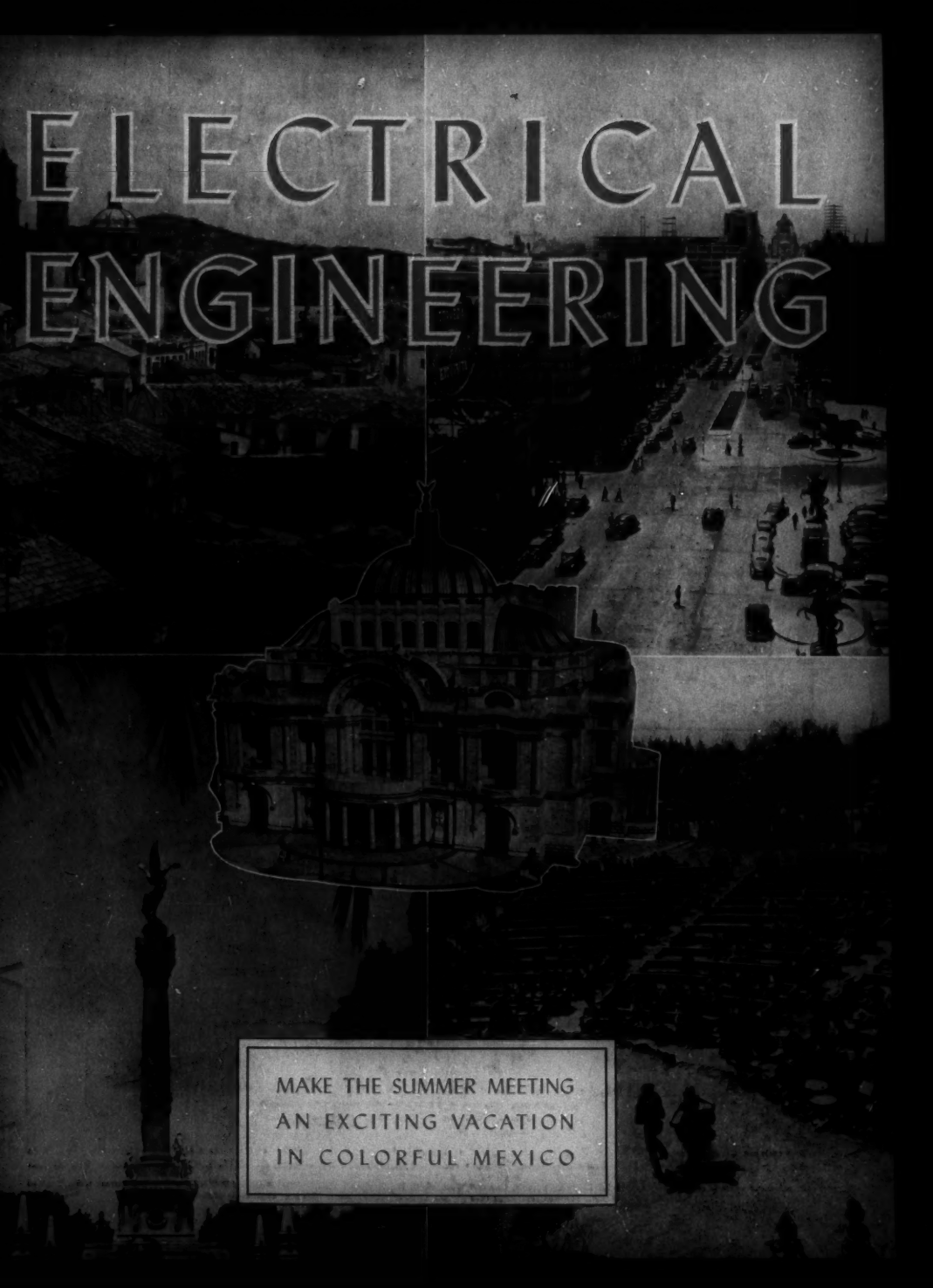
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1948

The Cover: Scenes from Mexico, site of the 1948 summer general meeting—upper left, view of the mining town of Taxco; upper right, the business section of Mexico City; lower left, Monument of the Independence on the Paseo de La Reforma, Mexico City; lower right, native dancers; center, meeting headquarters, the Palace of Fine Arts (Mexican Tourist Association photo).

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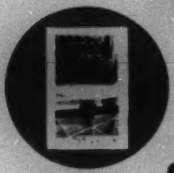

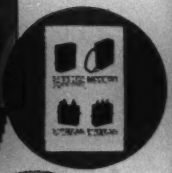

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HIGHLIGHTS.....

AIEE Special Publications. From time to time several articles or technical papers are grouped together and published as a single pamphlet. Two such pamphlets recently have been made available: "Tidd 500-Kv Test Project," and "Electric Power in the Pulp and Paper Industry." A list of all the special publications available appears in the advertising section of this issue (*page 48A*).

AIEE Meetings. Many Institute members and their families will be enjoying their vacations in Mexico this summer while attending the AIEE summer general meeting in Mexico City. General information regarding transportation, hotels, rate of exchange, and customs regulations appears in this issue (*pages 190–2*). Detailed information on any phase of the trip may be obtained by sending in the "request-for-information coupon" which appears in the advertising section (*page 54A*).

AIEE Conferences. The new type of AIEE national meeting known as the AIEE conference will make its debut late in March with the AIEE conference on electron tubes for instrumentation and industrial use. Objectives and organization of the conference-type meeting, and tentative program plans for this first conference, are covered in this issue (*page 189*).

AIEE Subcommittees. The subcommittees of the industry group, communications and science group, and the general applications group substantially completes the listing of the AIEE technical subcommittees (*pages 203–06*).

The Patent Question. Does patent consciousness interfere with co-operation between industrial and university research laboratories? The views expressed in this article on support a negative reply to this highly controversial question for, says the author, with its present patent system the United States has achieved "the greatest fertility in invention and the greatest industrial progress the world yet has seen" (*pages 135–6*).

The ENIAC. Computers have many different properties which make different types suitable for different operations. The electronic large-scale general-purpose digital type (of which the ENIAC is the only example now in operation) is completely flexible within the limits of its programming capacity. It can handle virtually any type of practical problem requiring numerical solution (within the limitations set by the capacity of certain components), but is economical only for problems which involve repetitious computations of the same type or an excess number of man-hours of numerical calculations (*pages 163–72*).

Nuclear Reactions Outlined. The third article of the series developed by the AIEE nucleonics committee describes the various varieties of nuclear reactions made possible by development of high-voltage accelerating devices. Much is still unknown about the "why's and wherefore's" of nucleonics, but great strides have been made toward complete comprehension of the forces and masses that exist within the nucleus shell. The series, as a whole, will provide an authoritative understanding of this rapidly developing scientific field (*pages 125–34*).

High-Voltage Measurement. "A simple method for accurately measuring voltages present on high-voltage systems during both transient and steady-state conditions without modifying the conditions producing the voltage to be measured has been developed" (*pages 154–7*).

Magnetic Sound on Film. The magnetic sound system has advantages in the recording, editing, and arranging of 35-millimeter professional productions. It is also especially well suited for 16-millimeter and 8-millimeter films, allowing the amateur to make sound pictures with simple inexpensive equipment (*pages 138–41*).

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China Plans Reconstruction. Faced with the almost impossible task of rebuilding and expanding the electrical utilities of China, the National Resources Commission has launched both a short-time alleviation program and a long-run building plan. Both are dependent upon use of Japanese reparations and foreign aid (*pages 146–9*).

Leakage Reactance Discussed. The causes and effects of leakage flux in electric equipment long have been recognized. Methods of analysis and calculation are still topics for open debate. Textbooks often separate discussions of leakage reactance by chapters on various equipment. This simple nonmathematical article gives an over-all view of leakage reactance as it exists in transformers, induction motors, synchronous machines, and d-c machines (*pages 142–6*).

Vibration Problems. A record of four typical types of balance problems as encountered in the field serves to broaden the engineers' knowledge of actual situations and to show the part that experience plays in the solutions of the problems (*pages 150–3*).

A-C Potentiometer. Although the value of the d-c potentiometer in the field of d-c measurements is well known, the a-c potentiometer has not enjoyed comparable popularity in the field of a-c measurements, possibly because the a-c bridge has provided a means of making measurements where indicating instruments were not suitable. However, the potentiometer almost always excels in the measurement of voltage and current, and generally has a more universal application than the bridge (*pages 173–81*).

Rubber Industry Uses Electronic Developments. Electronic controls have been applied to various co-ordinated drive systems in the rubber industry. Some unique applications have been developed, but most of the system can be adapted for other industrial applications. Three typical examples are discussed (*pages 119–24* and *188*).

Echo Testing. Supersonic waves can be used in testing for defects in metal parts as a complement to X-ray testing. A crystal is used to transform electric pulses into high-frequency sound wave and to detect echo pulses (*pages 181–5*).

Correction. In J. J. Smith's article "The Atom and Its Nucleus" (*EE, Dec '47, pp 1165–75*) the diameter of a heavy nucleus erroneously was stated to be approximately 10^{-3} centimeter. Actually the diameter is about 10^{-12} centimeter (*page 214*).

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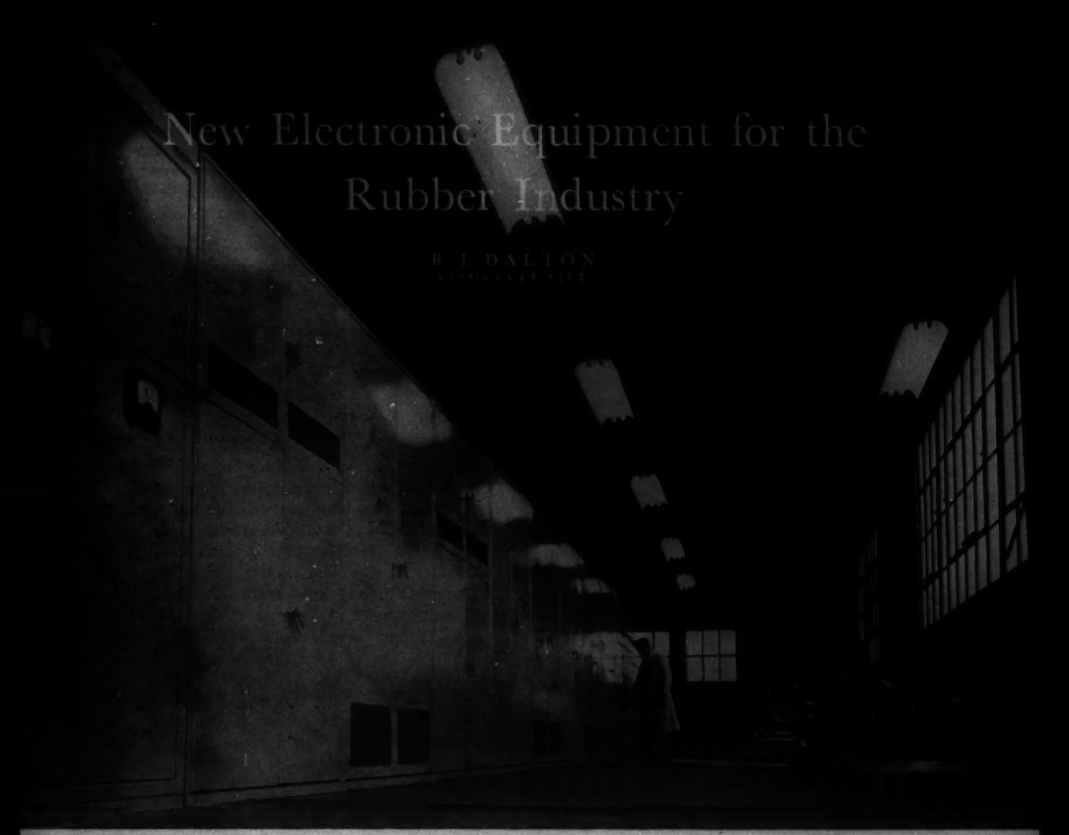


New Electronic Equipment for the Rubber Industry

B. J. DALTON
ASSOCIATE AIEE

The demonstrated performance and reliability of industrial electronic controls have enabled them to compete with older schemes of regulation. Three typical successful applications of electronic equipment are discussed here.

THE MYSTICISM of the "magic eye" of electronics of yesterday has been dispelled by the realization that electronic tubes and circuits are potent and dependable industrial tools when they are applied and used intelligently. Electronic-type control equipment, installed in the past 16 years, has demonstrated its ability to make important contributions in the rubber industry. Although the purpose of this article is to highlight those functions that are provided electronically, let us not forget that the electronic tubes and circuits are only a part of the composite of complete electric equipment. Due credit also should be given to the switchgear, magnetic control, generators, and motors which work side by side with electronic equipment to make complete operating systems.

Essential substance of a conference paper, "New Developments in Electric Equipment for the Rubber Industry," presented at the AIEE Middle Eastern District meeting, Dayton, Ohio, September 23–25, 1947.

B. J. Dalton is in the industrial engineering divisions of the General Electric Company, Schenectady, N. Y.

TUBER CONVEYERS

One of the first applications of electronic tubes in the rubber industry, made as early as 1931, was the thyratron-type grid-controlled rectifiers, used in conjunction with motors that drive tuber conveyers. Figure 1 shows a typical schematic flow diagram of a tuber conveyer which handles the rubber stock after it has been extruded through the die of a tuber.

Co-ordination of First Section With Tuber. Because underweight stock results in an inferior product, and overweight stock wastes expensive rubber, it is important to hold the weight of a given length of material at a constant value. The weight of a unit length of stock is influenced by the relationship of the speed of the first conveyer to the speed of extrusion, making it essential to

control the first conveyer speed properly. The problem of speed control, however, is difficult because it is not enough that the conveyer speed be proportional to the tuber screw speed; it also must follow the variations in extrusion speed caused by variations in stock temperature. Furthermore, because the stock leaving the tuber is hot and very soft, it is not desirable to have any physical contact with the material.

Electric drives with automatic electronic control can be of material assistance in co-ordinating the speed of the first conveyer section with the extrusion speed of rubber stock from the tuber head. Often the first conveyer section is used for continuously weighing the stock. In this instance the movement of the scale platform can be used to actuate a small control solenoid, as shown in Figure 1, which regulates the field of a d-c motor, and thereby the speed of the weighing conveyer, by means of a thyratron rectifier.

As the control signal from the solenoid is supplied to an electronic circuit, the weight error required to operate the solenoid is negligible. After the solenoid plunger weight has been counterbalanced, there remains a small differential of approximately two ounces between full stroke of the solenoid and zero stroke. In most applications it is not necessary to use the entire stroke of the solenoid and therefore the actual change in weight at the scale is very small.

The phase shifting circuit of the motor control is arranged so that when the plunger of the solenoid is removed, thus decreasing the solenoid reactance, the firing angle of the thyratron tubes is advanced to give a higher d-c output voltage. This increases the motor field current and thereby results in a lower motor speed.

Photoelectric equipment may be used to control the motor speed over a small range by accurately holding the position of a loop of rubber fixed with respect to the position of the photoelectric tube. Although photoelectric equipment has the obvious advantage of the elimination of mechanical dancer rolls which contact the material, its application is limited by several factors. Some materials when extruded do not have sufficient strength to form a loop for controlling a light beam. Also, the mechanics of some systems make such an application impractical. Where a solenoid reactor control can be used, a simpler electronic system results. Because the optical system always must be clean, lens cleaning may become a chore in dirty locations.

Co-ordination of Adjacent Sections. Co-ordination of adjacent sections of a tuber conveyer can be accomplished by means of a control solenoid actuated by a loop of material as shown schematically in Figure 1. The strip of rubber passes under a floating roll which actuates the control solenoid. Here again the "weightless" control solenoid will control the speed of the second conveyer to hold a given position of the rubber stock, irrespective of the speed of the first conveyer, the shrinkage of the stock, or the slippage of the stock on the belt.

Types of Conveyer Systems. A common electric drive for a tuber conveyer system consists of several d-c motors connected to the shop d-c bus, which many plants have, by means of conventional resistance-type motor starters. The fields of the conveyer motors can be controlled by means of thyratron rectifiers to give a total speed range of three- or four-to-one.

Recently, however, because of the need for speed ranges as high as ten-to-one, which is greater than can be obtained by the adjustment of motor fields, some adjustable voltage tuber conveyer drives have been built. In some instances a single adjustable voltage generator supplies all of the tuber conveyer motor armatures. The fields are controlled in the same manner previously described. In addition to operation over a wider speed range, this system also has the advantage of using, for a given horsepower rating, motors which are smaller because they are rated constant torque rather than constant horsepower. Furthermore, as a motor generator set, driven by an a-c motor, is used to supply all d-c power, a shop source of d-c power is not required.

The development of standardized electronic-type drive makes it feasible to supply an independent drive for each motor. This system is the most flexible of all. It offers all of the advantages of the single-generator adjustable-voltage drive, and it has the further advantage that, because each drive is a distinct unit, conveyer sections can be added or removed with a minimum of electrical problems. Also, the inherently wide speed range available in each unit makes accurate predetermination of individual conveyer section speed and load unnecessary. Because these drives are built

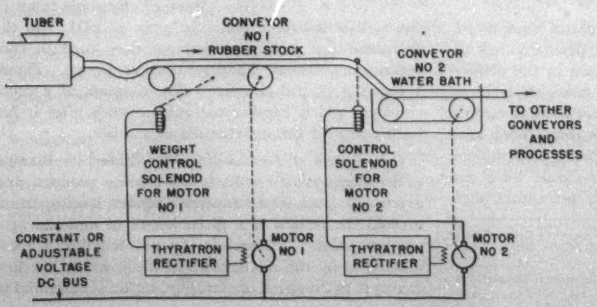


Figure 1. Typical schematic flow diagram of a rubber tuber conveyer

in large quantities in the horsepower ratings used for conveyers, they are available at relatively low cost.

CO-ORDINATED CALENDER TRAINS

Figure 2 is a schematic process flow diagram of a modern electronically co-ordinated calender train for rubber coating fabric. The general requirements for electric equipment for a calender train of this type are

1. Continuous operation at any preselected speed within a ten-to-one speed range.
2. Stepless speed control.
3. Threading at from five to ten per cent of top speed.
4. Accurate speed regulation at any preset speed.
5. Smooth acceleration by push button control to a preset speed.
6. Adjustment and automatic regulation of fabric tension by rheostatic control in certain portions of the train to meet fabric requirements.
7. Emergency stopping to meet the requirements of the National Safety Code.
8. Proper co-ordination of speeds and tension of all sections during starting, running, and stopping.
9. Flexible and simple selection of operation of given motors or groups of motors for threading or jogging forward and reverse.
10. Centralized control of all operating functions.

All of the magnetic and electronic controls, as well as the motor generator sets used to operate the four independent, but co-ordinated, adjustable-voltage drives, are located in the control room. The main operator's desk, in conjunction with other similar operator's desks, provides "finger tip" control of all sections of the drive.

Calender Drive. Because of processing requirements, it always has been necessary to operate calenders over a reasonably wide speed range. Although several methods have been employed to obtain this speed range, the most common drive in the past has been a d-c motor powered from a single- or 2-voltage shop bus. The speed range was obtained by adjustment of the motor field or, in the case of the 2-voltage system, by armature voltage selection as well as by field control. The normal operating speed range was generally three- or four-to-one. Recently, individual adjustable-voltage (Ward Leonard) drives have been applied to calenders to obtain continuous speed control over as high as ten-to-one speed range and to obtain co-ordination with electrically driven auxiliary motors. The individual adjustable voltage drive eliminates the need for a d-c

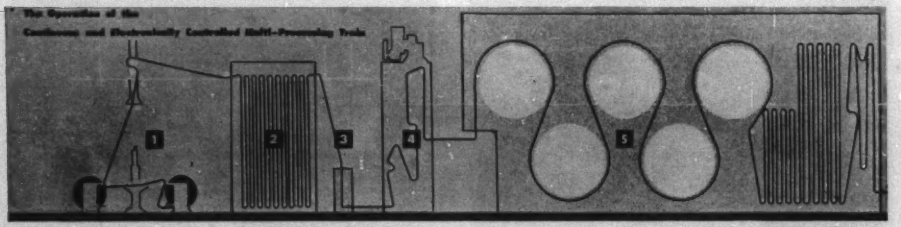
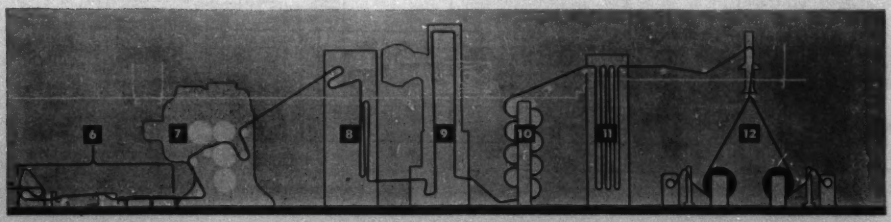


Figure 2. Process flow diagram for co-ordinated calender train

1—Rolls of fabric held by friction brake as fabric is pulled off by motor-driven pull rolls overhead
2—Festoon provides storage which may be used while changing supply rolls
4—Latex dipping unit, fabric is held at predetermined tension
5—Drying oven, fabric held at another predetermined tension
7—Four-roll calender coats both sides of fabric with accurately controlled thickness of rubber
6, 8—Motor-driven pull rolls for maintaining tension before and after calendering
10—Water-cooled drums prevent premature curing
11—Festoon provides storage capacity to be used while changing windup rolls
12—Motor-driven windup rolls; a fabric liner is placed between layers to prevent sticking



shop bus which often extends over an entire factory and thereby results in a less expensive over-all equipment if the cost of an equivalent constant voltage d-c power system is included in a cost comparison.

Figure 3 shows the main power circuit for the calender motor and generator and the associated electronic control circuits. The speed of the calender is controlled over a five-to-one range by adjustment of the generator voltage and over a two-to-one range by adjustment of the motor field. This method of operation provides maximum torque in the lower half of the operating speed range and essentially constant horsepower over the upper half of the speed range. All motor and generator field power is supplied by thyratron rectifiers which are electronically controlled to provide five important functions:

1. Accurate Speed Regulation. Accurate speed regulation is of particular importance on thin gauge stock where the effect of speed on gauge is most pronounced. When the calender speed is varied, the position of the roll journals in the bearings changes causing a small but important change in spacing between the rolls. Accurate speed regulation is also helpful in maintaining a given production rate and maintenance of speed aids threading the calender at low speeds.

The circuit of the electronic control shown in Figure 3 shows how the electronic features are obtained. The output voltage of the generator thyratron rectifier is controlled by changing the reactance of a saturable reactor the d-c winding of which is in the anode circuit of tube 2. Tubes 1 and 2 provide the speed regulating function by "comparing" the tachometer generator voltage with the reference voltage and actuating the saturable reactor to hold a given tachometer generator voltage.

A small d-c control power rectifier, which for the sake of simplicity is not shown, supplies power to all of the electronic control circuits. Voltage regulating glow tubes are used to stabilize this d-c output voltage so that a constant reference voltage is available irrespective of variations in the a-c input line voltage.

2. Preset Speed Control. And 3. Time Acceleration and Deceleration. Time acceleration and deceleration are provided electronically without the use of bulky multicircuit rheostats which are used in many systems. Tubes 3, 4, 5, and 6 and the associated circuits in Figure 3 provide the functions of preset speed and time acceleration and deceleration of the drive. Tubes 3 and 4 are connected in cathode follower circuits which results in the potential of lines 7 and 9 being the same. The several relay tubes shown are merely simple rectifier tubes that conduct current only when the anode of a specific tube is positive with respect to its cathode.

When the drive start button is operated, the main line contactor is closed and at the same time the contact across the timing capacitor is opened. As the timing rheostat and capacitor are connected across a fixed voltage source, lines 3 and 5, the timing capacitor will be charged at a rate determined by the size of the capacitor and the amount of resistance in the series rheostat. (This time can be adjusted from about 15 seconds to more than a minute total accelerating time.) When the increasing voltage reaches the preset level tube 6 conducts and the drive stops accelerating. As soon as current flows through the relay tube 6, the effect of the timing circuit is eliminated because the resistance of the speed control is much less than the resistance of the timing rheostat. If the speed control is readjusted

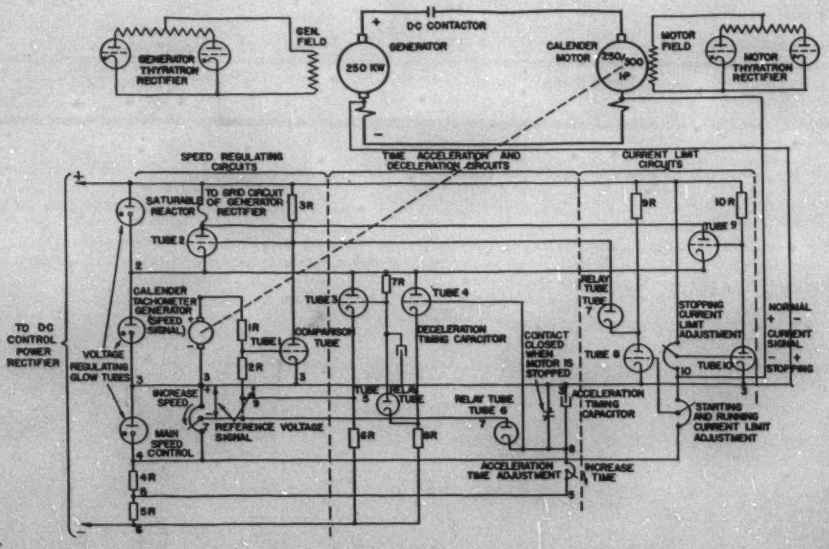


Figure 3. Power and electronic control circuits for calender motor and generator

to increase the speed, a similar sequence occurs. During the time the capacitor voltage is increasing, the grid of tube 4 gradually becomes more negative. Through the action of the cathode follower tubes the reference voltage slowly is increased. During acceleration the speed of the motor is regulated by means of the voltage on the timing capacitor. Although the charging characteristic of a capacitor is exponential, only the straight line section is used during acceleration. The accelerating time, therefore, is proportional to speed.

During deceleration, the action is somewhat different. If the drive is running at a high speed and the speed control rapidly is turned to a lower value (nearer to the potential of line 3), the grid of tube 4 rapidly will be moved more positive by the action of tube 6. Because the cathode of tube 4 follows its grid, the cathode of tube 5, the other relay tube, immediately will move more positive. The timing circuit connected to the anode of tube 5, however, will prevent its anode from moving positive rapidly. Therefore, during deceleration, the timing capacitor in the decelerating time circuit has control. When the anode of tube 5 again reaches the new cathode potential, the effect of the deceleration timing capacitor will stop and control again will become a function of the speed regulator.

Figure 4. Motorized windups are used to wind rubberized fabric and liner into package for temporary storage

Storage festoon and cooling rolls are in the background

4. Current Limit. The current limit feature incorporated in this control is helpful in the initial starting of the calender, when starting after repairs have been made, or during some abnormal overload of the calender. A current signal in the form of a voltage drop across the commutating fields of both the generator and the calender motor is fed into the control circuit at lines 3 and 10 in such a way that if the starting or normal running current should exceed the commutating limit of the d-c machine, tube 8, which is normally nonconducting, will conduct and thus tube 7 will "take over" from the speed regulator to control tube 2 to keep the generator output voltage at a very low value.

5. Emergency Stopping. Emergency stopping to meet the requirements of the National Safety Code also is provided by regenerative braking of the calender motor. During emergency stopping, the generator voltage is reduced to zero by closing the contact between lines 3 and 8, while the loop contactor *M* is held closed. The direction of current flow then is reversed because the motor acts as a generator. Tubes 9 and 10 then control the saturable reactor and, in turn, the generator field, to allow a rapid rate of stopping but prevent excessive armature current from flowing.

Precalender Auxiliaries. The precalender drive is, from a power standpoint, an independent adjustable-voltage drive. An independent drive is used for several reasons:

1. The precalender motors are operated over the ten-to-one speed range entirely by armature voltage control and would not operate properly from the main calender generator which has only a five-to-one voltage range.

2. Greater flexibility is provided than if power were supplied from the main generator. For example, when starting operation at the first of the week the calender is warmed up while running at low speed. At the same time, fabric is threaded through the entire precalender section. Independent control is needed to provide threading operation independent of the calender.

3. Better co-ordination of all motors over the ten-to-one speed range can be obtained by the use of an independent generator.

Normal operation of the precalender drive requires that the speed of the precalender sections match, at all times, the speed of the calender. The electronic control on the precalender generator, which is similar to that used on the calender generator, regulates the generator

Figure 5. A heavy duty truck tire in the process of manufacture

Reinforcing bead is in position to be rolled or stitched down. High and low speed, forward and reverse, is controlled by foot switches near the operator's foot

voltage by comparing the precalender generator voltage signal (an indication of the speed level of all precalender motors) with the voltage signal from the calender tachometer generator (an indication of calender speed). This system thereby provides co-ordination of the precalender speed with the calender during acceleration and deceleration as well as during normal running.

Controlling the voltage of the precalender generator, as a means of speed regulation, however, is not in itself adequate for a drive of this type. All fabrics have the characteristic that a very small change in elongation results in a large change in tension. Therefore, as the fundamental problem in processing fabric is the maintenance of proper tension, a means of controlling tension rather than speed must be provided.

Tension Control. Several different methods are feasible and are provided in this drive. Electronic tension control for drives of this type can be supplied basically in two ways:

1. By a dancer roll operating a control solenoid.
2. By armature current control.

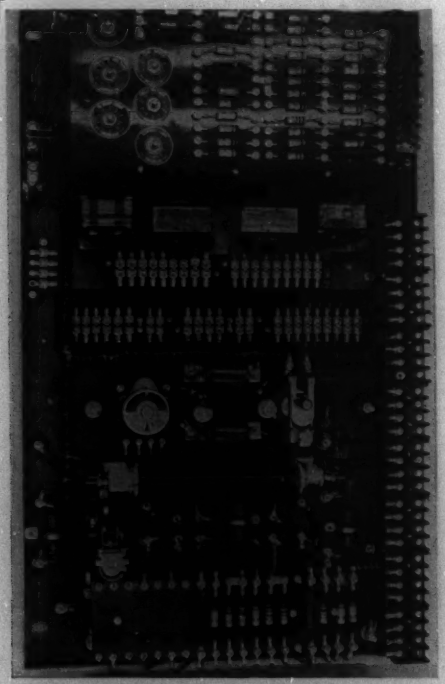


Figure 6. Back view of standard Thy-mo-trol drive showing method of construction for ease of installation and maintenance

A dancer roll should be used wherever possible because not only is it simple from an electrical standpoint, but also it provides a positive measure and control of tension. When tensions involved are small, it is often practical to use dead weight to obtain the desired tension. For fairly heavy tensions, when tension values are changed occasionally, it may be more practical to use an air-operated piston with an air pressure regulator to regulate the tension to be held. Heavy weights have a definite disadvantage from an operating standpoint unless applied where tension changes are not necessary. Current control of tension, however, has several distinct advantages over a weighted dancer roll

1. It provides an easily adjustable method of tension control.
2. It provides an indication by an ammeter of the tension actually being held.
3. It eliminates the need for floating rolls and associated mechanical equipment.

Its primary disadvantage is that armature current is an indication of total motor load only and thus not a true measure of fabric tension in those instances where fabric tension is only a portion of the total motor load. It, therefore, can be used to best advantage only when tension values are well defined and where the range of tension load on a single motor does not exceed approximately a five-to-one ratio.

Tension and Cooling Rolls. The primary function in this drive is the same as that of the precalender sections; namely, that of maintaining the proper tension relationship between the individual sections of the calender train. Here again, the generator voltage follows the calender speed. Because it is desirable to provide flexibility of tension adjustment on both tension rolls motors, current signals are used as a means of tension indication.

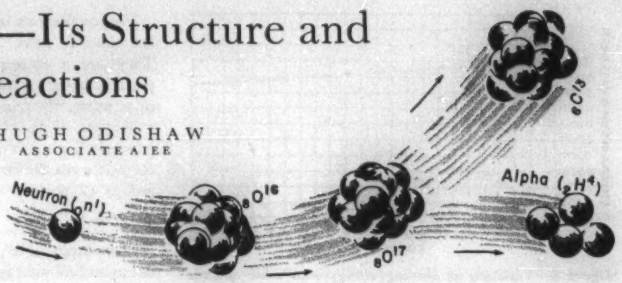
The tension in the cementer unit is controlled by the speed of the cooling drums motor. A solenoid reactor is used ahead of the cementer to adjust the speed of the cooling drums by changing the motor field strength.

Windup Section. Figure 4 shows the windup section of the train. The windup pull rolls motor, supplied with fixed field excitation, is the master motor of this group. Although voltage control of the windup generator sets the approximate speed of the motor, a control solenoid, located on the festoon following the cooling drums, "trims" the generator voltage by means of the electronic control system to adjust the speed of the windup pull rolls motor to hold the festoon platform near the top. While rolls are being changed, the festoon, which normally is run nearly empty, can be filled. After a roll change, the solenoid, acting through the electronic control, then overspeeds the entire windup section temporarily in order to remove the excess storage in the festoon. Time acceleration is provided on the build-up of the windup generator voltage so that after

(*Continued on page 188*)

The Nucleus—Its Structure and Reactions

W. E. SHOUPP HUGH ODISHAW
ASSOCIATE AIEE



Radium, once most fabulous and costly substance on earth, is faced with technological unemployment. Artificial radioactive materials produced by nuclear scientists at lower cost can be "tailored" to meet the need at hand. This is the third in a series of articles developed by the AIEE nucleonics committee.

UNTIL the discovery of natural radioactivity, the important part of the atom was its outer structure—in particular, the behavior of the electrons in the outer shells, for the rearrangement of these electrons accounts for chemical reactions. The tacit assumption of the nucleus as a simple, positive charge was thus adequate in the explanation of such reactions because the nucleus played no role in them. The growth of nuclear physics, however, suggested the existence of reactions involving only the inner portion of the atom.

The investigation of these reactions led to the realization that tremendous quantities of energy are released in transmutations of nucleuses and that these reactions are amenable to study, control, and utilization by man.

This suggests that the essence of matter is not atomic (in the sense that atoms are indivisible and fundamental particles of matter) but nuclear.

The atom is thus no longer the "building block" of the universe. And the so-called elements are no longer "elemental." The suspicion that more "elemental" units characterize the old elements has been demonstrated completely by nuclear physics. The structure of nucleuses, and hence of matter, hinges on the existence of these new units or particles, on their nature, and on the diverse relationships existing among them as explained in a previous article in this series[1] and summarized in Table I.

NUCLEAR STRUCTURE

The electric charge is the most important characteristic of the nucleus. Because the atom as a whole is electrically neutral, the number of outer orbital electrons is equal to the units of positive charge Z* of the nucleus. The letter Z is known as the atomic number. Elements possessing values of Z equal to 1 (hydrogen) to Z equal to 92 (uranium) have been found in nature except for Z equal to 61, 85, and 87. Recently four new elements have been created artificially, corresponding to Z equals 93 (neptunium), Z equals 94 (plutonium), Z equals 95 (americium), and Z equals 96 (curium).

Some naturally occurring elements are composed of mixtures of several different atoms having the same nuclear charge Z but differing in their nuclear weights. The various weights of atoms of a particular element are called isotopes. The whole number nearest to the atomic weight of a particular atom is called the "mass number" and is designated by A.

The atomic number subscript Z in nuclear notation therefore indicates how many protons there are in the particular nucleus—for example, helium $_2He^4$ has two protons while $_{15}P^{31}$ has 15. The mass number A is equal to the sum of the number of protons Z and number of neutrons N in the nucleus:

$$A=Z+N$$

The number of neutrons in the nucleus is then the difference between the superscript and the subscript in nuclear notation; for example, there are $N=31-15=16$ neutrons in the phosphorus nucleus $_{15}P^{31}$.

However, the mass of a nucleus is less than the sum of the neutron (1.00894) and proton (1.00758) masses of which the nucleus is composed. As explained in a previous article of this series[2], this can be interpreted by Einstein's law of the equivalence of mass and energy ($E=mc^2$) and indicates that the "binding energy" that holds the nuclear particles together decreases the total energy of the nucleus. One mass unit turns out to be equivalent to 0.00149 erg or 931 million electron volts.

NUCLEAR FORCES

The concept of the nucleus as a tight cluster of uncharged and positively charged masses suggests that

W. E. Shoupp is manager of the electronics and nuclear physics department of the Westinghouse Research Laboratories, East Pittsburgh, Pa. Hugh Odishaw is assistant to the director of the Bureau of Standards, Washington, D. C.

* The symbol Z customarily is used to denote nuclear charge; P also is used but there is danger of confusing it with the identical chemical symbol for phosphorus.

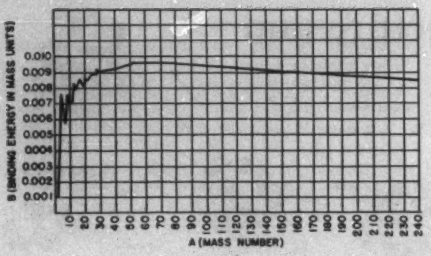


Figure 1. Variation of binding energy with mass number

the nucleus cannot be a static, impotent entity. On the contrary, violent forces contend within it. The electric repulsive force between protons, called the coulomb force, varies inversely as the square of the distance of their separation. In view of the small diameter of the nucleus itself, of the order of 10^{-12} centimeter, the coulomb forces are substantial, and protons within the nucleus tend to fly apart. There then must exist other forces, attractive in nature, tending to hold nuclear particles together if atoms are to exist at all. The net excess of the attractive forces over the repulsive forces between nuclear particles is represented by the binding energy.

These nuclear characteristics permit the following deductions:

1. The mere existence of nucleuses reveals that the specifically nuclear forces are much greater than the coulomb forces if the nucleuses contain protons.

2. The proton–neutron force is probably the strongest force in nucleuses. If this were not true, most stable nucleuses would consist either entirely of protons or neutrons.

3. The fact that the number of protons is equal to the number of neutrons ($Z=N$, approximately) signifies that the proton–proton (p–p) force and the neutron–neutron (n–n) force are about equal. If this were not true, then isotopes of maximum stability ($_6C^{12}$, $_2He^4$, $_7N^{14}$, and so forth) would not occur for equal numbers of protons and neutrons, but would tend to occur for larger Z or larger N.

In Figure 1 the binding energy per particle is plotted as a function of the mass number for most known nucleuses. Elements around A equals 65 (copper, nickel, and zinc) are more stable than either lighter or heavier elements. The approximate equality of Z and N for lighter elements (A is less than 40) bears out the deduction regarding the strength of the basic nuclear force—otherwise a prevalence of protons or of neutrons would be natural (Figure 2). As the nucleuses increase in size, however, it appears that the increased coulomb forces (because of the larger number of protons) eliminate some of the protons, and the heavier stable nucleuses tend to have fewer protons than neutrons (Figure 2).

The oscillations in the B–A curve of Figure 1 for A less than 30 have considerable structural significance. They are a consequence of the formation of alpha-particle groups (called subshells) in the nucleuses—in a sense, these nuclear subshells can be viewed as analogues of the electron shells of the outer atom. Maximum nuclear stability points are obtained when the nucleuses are composed of completed alpha-particle groups (2 protons + 2 neutrons)—that is, when

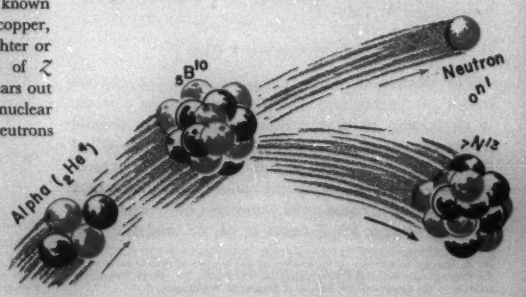
$$Z=A/2=N$$

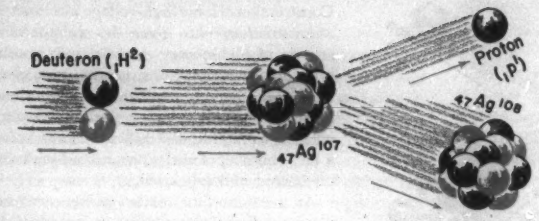
(for example, $_2He^4$, $_6C^{12}$, $_8O^{16}$, $_{12}Mg^{20}$). Again, the electron-shell analogy, with definite orbits and energy levels for the outer electrons, is helpful.

For heavy nucleuses (Z is greater than 90) the coulomb repulsion between the protons in the nucleuses becomes increasingly important as the charge of the nucleuses increases much more rapidly than the volume for increasing A. This increasing importance of coulomb repulsion for heavy nucleuses therefore tends to decrease the binding energy per particle B. This continues until nucleuses are no longer stable. The unstable point occurs for values for Z above 92 and for A about 235. This instability condition, resulting from the competition between the coulomb electric repulsion and the attractive nuclear forces, accounts also for the radioactive instability of the heavier elements (radium, uranium, and so forth) and for the nonexistence in nature of elements beyond uranium.

It is this decrease in binding energy for large values of A (Figure 1) that makes it possible to extract energy from the nucleus. Consider the disintegration of a heavy nucleus—for example, uranium $_{92}U^{235}$ to which a neutron has been added giving $A=236$—into two equal nucleuses having masses of $A=118$. The nucleuses having mass $A=118$ are more stable; so the sum of their masses is less than that of the heavy nucleus. We see that the binding energy per particle B in Figure 1, drops from 0.0093 mass unit for $A=118$ to 0.0085 mass unit for $A=236$. The total energy gained in such a process is then the number of particles concerned multiplied by the change in binding energy per particle:

$$236\,(0.0093-0.0085)\,931=175 \text{ million electron volts}$$





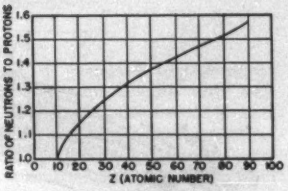


Figure 2. Neutron-proton ratio versus the atomic number

where the factor of 931 is introduced solely to obtain energy in million electron volts.

This simple calculation shows that 175 million electron volts are available in such a process. The nuclear fission reaction used in the atomic bomb is a process of this type. The nuclear transformation liberates the energy incident to the decrease in binding energy per particle B for large atomic numbers A. Greater energy could be obtained if heavy nucleuses disintegrate into somewhat lighter nucleuses than those used in this example or by combining very light nucleuses into heavier ones.

PARTICLES AND DYNAMICS

Although the nucleus of the atom has been described as consisting of protons and neutrons, exerting and undergoing certain forces, still other particles are involved in nuclear transformations (see Table I). The discovery of these particles, as indeed of the proton and neutron, and their importance arises from the dynamic nature of nucleuses.[1] In all, 12 particles are associated with nuclear physics.*

In addition to the neutrino, mentioned in Doctor Smith's article, there is the antineutrino. Not only are both nonmaterial—they well may be nonexistent, for they are, at present, hypothetical entities postulated to account for certain nuclear disintegrations. When positrons or electrons are emitted by radioactive substances, it is considered that an unstable nucleus passes into a nucleus of greater stability. Electrons or positrons do not exist in the interior of nucleuses; however, as they are observed to be present in nuclear disintegrations, it is necessary to assume that they are "created" in the moment of emission.

In such a transformation, noting that there are energy levels in the nucleus, particles ought to be emitted with a discrete energy similar to that occurring in gamma-ray emission. The energy distribution of the emitted electrons or positrons is not discrete; in fact, a continuous distribution of energies up to a certain maximum value is observed experimentally.

This and other discrepancies are explained by assuming that a neutral particle (the neutrino) is emitted along with the electron or positron during each radioactive disintegration. The neutrino possesses energy and angular momentum but has a mass less than one-tenth that of the electron. It has not been observed experimentally, but its existence has been rather well established.

The mechanism of beta-particle emission then may be considered to be the result of a neutron breaking up into a proton, neutrino, and an electron—the latter being emitted as a beta particle.

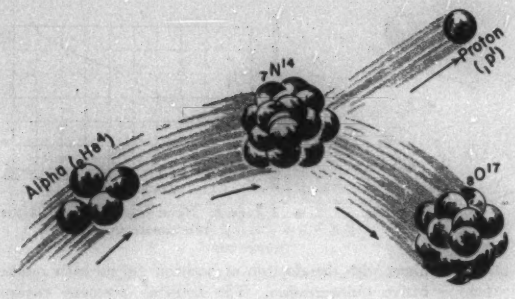
The converse reaction to account for positron emission also occurs. In this case, instead of the neutrino, a similar particle called the antineutrino, as well as a positron and a neutron, is emitted according to this assumption. The theory postulating the existence of the neutrino and the antineutrino is the only one that accounts for all of the present experimental observations. As such, it is valuable, but most scientists believe that fuller knowledge of radioactive transformation will require a modification of the theory.

The existence of 12 particles—real or theoretical ones—indicates the complexity of the nuclear problem, even aside from the several forces that prevail in the nucleus. The analysis of relations among protons and neutrons alone is difficult, for in all but the lightest elements the number is so large that rigid mathematical solutions are almost impossible. Hence, statistical quantum-mechanical methods are employed, yielding a picture of the nucleus as a sort of liquid droplet. Energy states and shell structure follow in a manner reminiscent in some ways of the outer atomic structure and in others of a hydrogen liquid droplet. Such forces as the coulomb, saturation, surface tension, and Van der Waals are involved.

Incomplete though our knowledge is, it has proved adequate in predicting much of the behavior of nucleuses in nuclear reactions. For this reason, if for no other, present concepts of the nucleus are valuable. They have permitted the creation of artificial isotopes. They have enabled us to cause nuclear disintegrations in the laboratory. They have led to the production of the atomic bomb, and the peaceful utilization of nuclear energy depends primarily on economic and political factors—not physical or technical ones.

It is these confirmations that promise a fuller knowl-

* Actually there are three kinds of mesons—positive, negatives and neutral. For simplicity, these are grouped as one in Table I.



edge of nuclear phenomena and, concomitantly, of the nature of matter. In the long run, this is the goal of nuclear physics.

NUCLEAR REACTIONS

Artificial transmutation of the elements, vainly sought by alchemists for centuries, was discovered less than 30 years ago. In the short time since, nearly a thousand nuclear reactions have been produced in the laboratory. In such reactions chemical elements have been changed into other chemical elements—that is, nucleuses have been built up and torn apart in the alchemy of atom smashing.

These reactions, in addition to enabling the production of an enormous family of radioactive substances important in medicine and engineering, provide the only method of investigating nuclear structure and nuclear forces, permitting scientists to postulate upon the basic structure of the universe. It was such reactions that finally led to the realization of atomic explosives in which fast neutrons are used to smash uranium into two lighter elements characterized by a smaller total mass and a consequent release of a vast quantity of energy. And it is the same body of knowledge that promises peaceful uses of atomic energy—probably, in the case of uranium, through reactions induced by slow neutrons.

Prior to 1932, atom smashing was limited to the use of naturally occurring alpha rays as from radium for the atomic bullets required to penetrate nucleuses. Construction of large high-voltage machines—atom smashers—has given the scientist new sources of high-energy particles such as protons, neutrons, deuterons, gamma rays, electrons, and helium nucleuses. With these powerful tools, producing particles having energies as high as 400 million electron volts, a large number of nuclear reactions have been discovered and tabulated.

At the same time, atom smashers are producing radioactive materials in considerable quantities for medical and research applications. Artificial radioactive substances are made at only a fraction of the cost of natural radium, leading to greater and more prolific use in radiography and medicine.

NUCLEAR AND CHEMICAL REACTIONS

Nuclear reactions, which deal with changes in the atomic nucleus itself, have many of the same characteristics as chemical reactions, which involve only the electrons in the outer orbits surrounding the nucleus. In fact, they generally are written in the same manner except that chemical compounds are replaced by atomic nucleuses. For example, compare the following two reactions, the first is the common chemical reaction of combustion, and the second, nuclear:

$$C + O_2 \rightarrow CO_2 \qquad (1)$$

$$_6C^{13} + {}_1H^1 \rightarrow {}_7N^{13} + {}_0n^1 \qquad (2)$$

The first reaction states that one atom of carbon unites with two atoms of oxygen to form one molecule of carbon dioxide. The subscripts indicate the relative number of atoms involved in the reaction.

The second reaction states that a carbon nucleus bombarded by a proton (the hydrogen nucleus) forms a nitrogen nucleus and a neutron. Here the subscripts indicate the positive electric charge of the nucleus. This is the number of protons in the nucleus of that element and is also the position or number of that element in the scale of elements. The superscripts indicate the total number of protons and neutrons in the nucleus.

Nuclear reactions, however, frequently are written in another manner where the reaction of equation 2

Table I. Properties of the "Particles" of Nuclear Physics

	Proton	Neutron	Alpha-Particle (α)	Deuteron	Beta-Particle (β)	Positron	Meson	Gamma Rays (γ)	Neutrino	Anti-Neutrino
Nuclear symbol	$_1H^1$	$_0n^1$	$_2He^4$	$(_1H^1+_0n^1)_1D^2$	$_0e^{-1}$	$_0e^{+1}$			$_0\nu^0$	$_0\bar{\nu}^0$
Charge, electrostatic units	$+4.80\times10^{-10}$	0	$+9.60\times10^{-10}$	$+4.80\times10^{-10}$	-4.80×10^{-10}	$+4.8\times10^{-10}$	$\pm4.8\times10^{-10}$ (or neutral)	0	0	0
Mass units of electronic mass (9.02×10^{-28} gram)	1838	1838	7352	3676	1	1	20 to 200	0	<0.1	<0.1
Mass relative to $_8O^{16}=16$	1.00758	1.008939	4.00280	2.01416	0.00055	0.00055	0.01 to 0.1	0	<0.00005	<0.00005
Mass energy (mc^2), million electron volts	938	939	3720	1876	0.511	0.511	5 to 50	0	<0.05	<0.05
Mechanical moment in units of $h/2\pi$ (h = Planck's constant)	1/2	1/2	0	1	1/2	1/2	Unknown	0	Unknown	Unknown

is rewritten into this shorthand form:

$$C^{13}(p, n)N^{13} \qquad (3)$$

Here, the incident projectile and the ejected light particle are grouped together in the brackets in the center of the reaction, where p denotes the bombarding proton and n the ejected neutron. Thus, the equation takes the form: bombarded nucleus (bullet, fragment) resulting nucleus.

The part in brackets (p,n) frequently is used to describe reactions of this type. This case represents a proton, neutron type of reaction, one of the more frequent of nuclear reactions.

Other symbols used in the brackets to describe nuclear reactions are for other atom-smashing projectiles and other resulting emitted particles or energies and give reactions of several other types represented by (n,p), (n,α), $(n,2n)$, (p,α), (p,d), (d,p), (d,n), (d,α), (α,p), (α,n). Sometimes the incident bombarding projectile simply is captured by the target nucleus; typical reactions of this type in which a neutron or a proton is captured are indicated by (n,γ) and (p,γ), inasmuch as no particle is emitted, but a gamma ray is formed that carries away the excess energy.

ENERGY BALANCE IN NUCLEAR REACTIONS

In chemistry some reactions require the addition of heat, or energy, to cause the reaction to proceed while in others, such as equation 1, energy or heat is given off. Precisely the same condition exists in nuclear reactions, and the terms endothermic and exothermic similarly are used to describe whether energy is required or is given off in the process. Like chemical equations, nuclear equations thus can be represented more accurately by including the term Q (energy of reaction or energy balance). Consequently equation 2 should be written,

$$_6C^{13} + {}_1H^1 \rightarrow {}_7N^{13} + {}_0n^1 + Q \qquad (4)$$

When the energy balance or Q-value is positive, energy is emitted and the reaction is exothermic. When the energy balance Q is negative, the reaction is endothermic and energy is absorbed in the process.

The magnitude of the energy balance is easy to compute if the masses of the reaction nucleuses or atoms containing these nucleuses are known. Consider, for example, the nuclear reaction caused by the bombardment of the metal beryllium ($_4Be^9$) with deuterium nucleuses ($_1D^2$) accelerated in an atom smasher, producing boron and a neutron. In such a reaction neutrons are emitted and the various nuclei have the following masses:

$$\begin{aligned} &{}_4Be^9 + {}_1D^2 \rightarrow {}_5B^{10} + {}_0n^1 + Q \\ &9.01503 + 2.01471 \rightarrow 10.01618 + 1.00894 + Q \\ &11.02974 \text{ mass units} \rightarrow 11.02512 \text{ mass units} + Q \end{aligned} \qquad (5)$$

The sum of masses of the nucleuses on the left side of the equation is greater than that of the right-hand nucleuses by the energy balance:

$Q = 0.00462$ mass units
$= 4.30$ million electron volts.

When the reaction is examined experimentally, neutrons having energies commensurate with these calculations are observed. Indeed, this reaction is one of the most commonly used methods of securing neutrons. The yield of neutrons exceeds that from any other known reaction utilizing bombarding deuterons with energies of a few million electron volts.

Reactions that are energetically possible usually can be made to take place. The yield, however, is a function of the energy of the bombarding particle. For observable yields from nuclear reactions, the voltage used to accelerate the bombarding projectiles frequently must be millions of volts. One exception to this is the H^2 (d,n) He^3 reaction where neutrons are observed for bombarding energies of only 10,000 volts.

NEUTRON-INDUCED REACTIONS (n, γ) AND PHOTO-DISINTEGRATION (γ, n)

When a projectile neutron strikes a nucleus of mass A and charge Z, the most common nuclear reaction is one of simple capture. A reaction of this type is represented by (n,γ) because a gamma ray is emitted during the process,

$$_0n^1 + {}_ZX^A \rightarrow {}_ZX^{A+1} + \gamma \qquad (6)$$

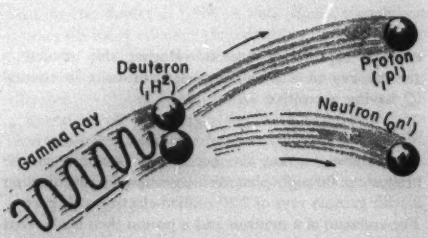
where the symbol X represents the nucleuses involved. The resulting nucleus is an isotope of the target nucleus and is one unit heavier. Because those nucleuses that exist in nature have lasted for thousands of years, they are generally the most stable ones. It follows that the resulting $_ZX^{A+1}$ isotope is less stable and is frequently radioactive. Hence the product nucleus may emit electrons, positrons, or gamma rays.

A reaction of this type, for example, is produced when neutrons are allowed to fall upon silver:

$$_{47}Ag^{107} + {}_0n^1 \rightarrow {}_{47}Ag^{108} + \gamma \qquad (7)$$

$$_{47}Ag^{108} \xrightarrow[\text{half-life}]{2.3 \text{ minutes}} {}_{48}Cd^{108} + {}_{-1}e^0 \qquad (8)$$

In this reaction ordinary silver is made into a radioactive silver isotope $_{47}Ag^{108}$ by the neutron bombardment. The radioactive silver isotope then decays into stable cadmium $_{48}Cd^{108}$ by emitting an electron.



This reaction is observed frequently—even the silver coin in one's pocket after being in the vicinity of a neutron source (such as a cyclotron) reveals a definite activity.

Because a neutron is captured in such a reaction, an amount of energy equal to the neutron binding energy must be given off. The binding energy per particle is usually between six and nine million electron volts and gamma rays having roughly this energy frequently are observed when (n,γ) nuclear reactions occur.

Reactions of this type occur only for discrete neutron energies, and generally speaking (n,γ) reactions are said to be "resonance reactions"—that is, the energy of the bombarding particle (the neutrons) must be almost exactly equal to the difference between two energy levels in the "compound" nucleus. If the bombarding neutron is moving much faster or slower the reaction does not follow. A transition then occurs between these two levels in the compound nucleus, and the energy difference is given off in the form of a gamma ray.

The frequency of this electromagnetic radiation, ν, is determined by the energy E divided by Planck's constant ($\nu = E/h$). Heavy nucleuses have a great number of closely spaced energy levels; therefore, neutrons of nearly any energy are captured. However, in the lighter elements, where the number of levels are fewer, (n,γ) reactions occur somewhat less frequently. Roughly, 200 reactions of the (n,γ) type have been observed, and studies of these resonance reactions have been most important in constructing theories of heavy nucleuses.

The inverse to the (n,γ) reaction is the photodisintegration reaction (γ,n). As an example of reactions of these types consider first the formation of a deuteron when a neutron captures a proton. During this process a gamma ray of 2.20 million electron volts is emitted (Q having a positive value):

$$ {}_1H^1 + {}_0n^1 \rightarrow {}_1H^2 + \gamma Q \qquad (9) $$

The inverse reaction also occurs. A deuteron can be broken up through photodisintegration by illuminating it with gamma rays of 2.20 million-electron-volt energy. The emission of a neutron and a proton then is observed as follows:

$$ \gamma + {}_1H^2 \rightarrow {}_0n^1 + {}_1H^1 + Q \qquad (10) $$

and in this reaction $Q = -2.20$ million electron volts. The importance of this reaction is that it offers the most accurate method for the determination of the mass of the neutron (1.00894), which, being electrically neutral, is not susceptible to easy analysis.

All other (γ,n) reactions require greater energy than that needed to disintegrate the deuteron. Reactions in beryllium and phosphorus and a few other light elements have been observed. The Q value in (γ,n) reactions is negative, that of (n,γ) reactions is always positive.

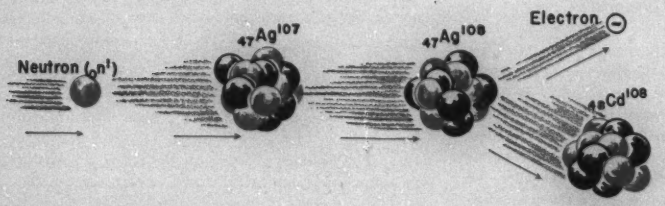
OTHER REACTIONS INDUCED BY NEUTRONS

Neutrons can cause the emission of particles as well as gamma radiation from nucleuses. In fact, (n,α), (n,p), and $(n,2n)$ reactions all have been observed. Reactions of the (n,α) or (n,p) type are easy to observe in a cloud chamber when the target nucleus is available in gaseous form as with targets of carbon, oxygen, fluorine, and neon. In such cases the gas in a chamber is supersaturated by a vapor. Droplet tracks resulting from the ionization produced by charged particles passing through this atmosphere can be observed visually and measured photographically, for example:

$$ {}_8O^{16} + {}_0n^1 \rightarrow {}_6C^{13} + {}_2He^4 \qquad (11) $$

Forked tracks are caused by the ${}_6C^{13}$ products nucleus and the alpha particle (${}_2He^4$). The neutron being uncharged does not produce ionization and consequently does not cause a track to appear in the cloud chamber. Its presence is immediately obvious, however, because there must be some reason for the forward momentum of the two observed ionizing particles.

Reactions of the (n,α) type have been found for nearly all elements, although it is frequently difficult to establish this point definitely for very heavy substances, because many competing reactions are also present. A particularly valuable reaction is the $B^{10}(n,\alpha)Li^7$ transmutation. This reaction is prolific and is used to measure the intensity of neutron sources. Because the neutron is not an ionizing particle, it is difficult to detect. However, if the neutrons are allowed to enter a chamber containing a gaseous form of B^{10}, the alpha particles produced by this reaction can be detected easily by amplifying the pulses of ionization they produce when they are emitted in the chamber. The compound, boron trifluoride, is used as a source of boron and the ionization is amplified by conventional vacuum-tube pulse rectifiers. By such means ionization produced



by single alpha particles can be measured, and so individual neutrons are detected.

Reactions of the (n,p) type form a product nucleus that has the same mass number A as the target nucleus and consequently may retransform into the target element by the emission of an electron. These reactions are energetically probable only for high-energy neutrons and for light target materials. For this reason (n,p) reactions are not prolific, and consequently they are more of academic interest than of practical importance for the formation of radioactive substances.

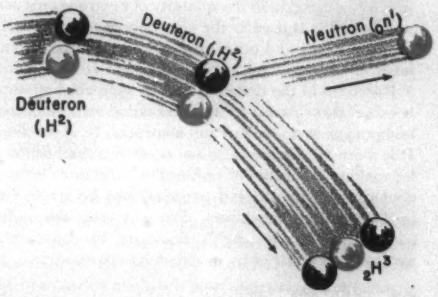
Reactions of the $(n,2n)$ type lead to the production of a lower isotope of the bombarded target just as do (γ,n) reactions. Therefore it is frequently difficult to determine which of these two reactions is producing a particular radioactive isotope. The $(n,2n)$ reaction is observed only for bombarding neutrons of extremely high energy and is identified through the formation of radioactive isotopes of the target nucleus. More than 30 elements spread between beryllium and uranium have been shown to disintegrate in this unusual manner.

SLOW AND FAST NEUTRONS

While fast or high-energy neutrons may cause nuclear reactions, slow ones, surprisingly enough, often react more violently. If the reaction, in which a radioactive isotope of silver is formed, equation 7 is carried out by immersing the neutron source and the silver target within a substance rich in hydrogen (such as water or paraffin), the yield of radioactive silver increases some tenfold. The collisions of the neutrons with the hydrogen nucleuses (protons) slow down the neutrons sufficiently so that resonance reactions occur. In fact, neutrons lose (on the average) roughly 70 per cent of their energy each time they collide with a hydrogen nucleus. Relatively few collisions are required to reduce high neutron energies to the range that resonance (n,γ) reactions occur (0 to 1,000 volts). For example, a 5-million-electron-volt neutron is reduced by 14 successive collisions to one having an energy of less than one electron volt. About 2.5 inches of paraffin is the optimum thickness to reduce neutron energies to the resonance range. If the thickness of the paraffin becomes too great, many of the neutrons become absorbed by uniting with protons in the (n,γ) nuclear reaction. Paraffin thinner than 2.5 inches allows large fractions of the projectile neutrons to escape with consequent loss in effectiveness.

Slow neutrons are much more effective in certain nuclear transmutations for another reason. Because they move so slowly they spend more time in the vicinity of the target nucleuses; therefore, their probability of capture is much greater than if they passed the target quickly. The effect is described by stating that the probability of a nuclear reaction taking place with a slow neutron (engaged in other than resonance reactions) is inversely proportional to the speed of the neutron.

These properties of neutrons lead to unusual requirements for the protection of workers in nuclear physics laboratories or in hospitals where intense beams of neutrons may be present. Tanks of water or blocks of paraffin of considerable thickness are required to slow down the neutrons. Then an absorber for the slow neutrons must be used. For this purpose cadmium metal is very suitable because it strongly absorbs neutrons of 0.17-electron-volt energy. Finally, some neutrons are captured by the reaction (n,γ), and so the appropriate amount of lead or steel is necessary to stop the gamma rays given by this process. Such complicated arrangements serve to emphasize that operations involving nuclear radiations must be controlled carefully by competent operators and scientists.



DEUTERON-INDUCED REACTIONS

Because the deuteron is positively charged it cannot enter other nucleuses and cause transmutations as simply as does the neutron. Deuterons are repelled by other positively charged target nucleuses and consequently must be accelerated to high velocities before they can cause a disintegration. Various machines have been designed for this purpose. Cyclotrons able to produce energies of approximately 200 million electron volts are being put into operation.

The electric coulomb repulsion force between two positive charges (such as a deuteron and a target nucleus) varies inversely as the square of the distance between centers and directly as the product of the two charges. Because the deuteron ($_1H^2$) is only singly charged, it is generally more effective than doubly charged particles ($_2He^4$) in producing transmutations. However, compared with neutrons they are some million times less effective.

Reactions of the (d,γ), (d,n), and (d,p) type have been observed, and have been studied in great detail. Two of the (d,n) reactions are of particular significance in that they furnish convenient sources of neutrons:

$$_1H^2 + {}_1H^2 \rightarrow {}_2He^3 + {}_0n^1 \qquad (12)$$

occurs for energies as low as 10,000 volts and is used as a prolific source of neutrons in small atom smashers operating at low voltage.

The neutrons emitted by this reaction all have the same energy, approximately 2.5 million electron volts. This fact makes the deuteron-neutron reaction valuable for nuclear studies because this is the only strong source of fast neutrons of constant energy. However, for atom smashers operating at voltages above 1 million electron volts, the beryllium-to-boron reaction, Be (d,n)B, surpasses this reaction in the quantity of neutrons produced and therefore is used as the chief source of neutrons for cancer therapy and other applications requiring intense neutron beams.

Reactions of the deuteron–proton type are important because they result in the formation of radioactive isotopes just as do the neutron absorption (n,γ) reactions. It is more advantageous to use deuterons than neutrons for making quantities of radioactive substances because deuterons (being charged particles) can be accelerated in high-voltage machines. For example, the radioactive silver isotope Ag^{108}, described in equation 7, also can be produced by deuteron bombardment:

$$_{47}Ag^{107} + {}_{1}H^{2} \rightarrow {}_{47}Ag^{108} + {}_{1}H^{1} \qquad (13)$$

$$_{47}Ag^{108} \xrightarrow[\text{half-life}]{2.3\ \text{minutes}} {}_{48}Cd^{108} + {}_{-1}e^{0} \qquad (14)$$

The deuteron–proton reaction occurs with great probability compared with other reactions between charged particles. In this instance it is not necessary that the deuteron penetrate all the way through the coulomb potential barrier of the target nucleus to cause the reaction to take place. In fact, the deuteron, as it approaches the nucleus, breaks up into a proton and a neutron; the proton is deflected away by the electric field, and the neutron is absorbed forming the reaction as indicated in equation 6. The proton then acts as a carrier, enabling the neutron to be shot electrically into the proximity of the target nucleus.

ALPHA-PARTICLE INDUCED REACTIONS

Because alpha particles are available from natural radio active substances such as RaC′ ($_{84}Po^{214}$) they were the first projectiles used to cause atomic disintegrations. Lord Rutherford in 1919 achieved the first successful nuclear disintegrations by bombarding nitrogen gas with RaC′ alpha particles. The protons in the corresponding (α,p) reaction were observed by the illumination they produced upon striking a fluorescent screen. The reaction observed was

$$_{7}N^{14} + {}_{2}He^{4} \rightarrow {}_{8}O^{17} + {}_{1}H^{1} \qquad (15)$$

There was considerable doubt at the time that such a reaction was observable because the size of the alpha particle ($_{2}He^{4}$) as well as the target nucleus ($_{7}N^{14}$) was known to be less than 10^{-12} centimeter in diameter. The probability of scoring a hit on such a small target with a still smaller projectile was slight indeed. Furthermore, the electric coulomb repulsion between the alpha particles is quite large and it was doubtful that the RaC′ alpha particles possessed sufficient energy to approach the nucleus close enough to cause disintegration.

However, the experiment was successful and it launched the study of nuclear reactions that has developed into the complex science of nuclear physics. It is no longer necessary to depend upon natural sources for alpha particles for bombarding purposes. Nucleuses of helium can be accelerated in conventional atom smashers and intense beams of alpha particles created. Many nuclear reactions of the (α,p) and (α,n) types have been produced.

Artificial radioactivity first was discovered by the production of radioactive nitrogen and phosphorus from boron and aluminum respectively by reactions of the (α,n) type,

$$_{5}B^{10} + {}_{2}He^{4} \rightarrow {}_{7}N^{13} + {}_{0}n^{1} \qquad (16)$$

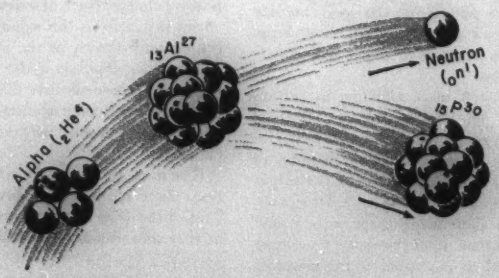
$$_{13}Al^{27} + {}_{2}He^{4} \rightarrow {}_{15}P^{30} + {}_{0}n^{1} \qquad (17)$$

These reactions of the (α,p) type are important because they permitted the investigations of energy levels in compound nucleuses, which has been heretofore difficult.

The protons ejected in (α,p) reactions frequently are observed to consist of several discrete energies. Four proton energy groups are observed in the $_{5}B^{10}(\alpha,p)_{6}C^{13}$ reaction, corresponding to energy balances Q of 3.3, 0.5, 0.1, and −0.8 million electron volt, thereby establishing the energy level structure in the stable nitrogen compound nucleus $_{7}N^{14}$.

REACTIONS INDUCED BY PROTONS

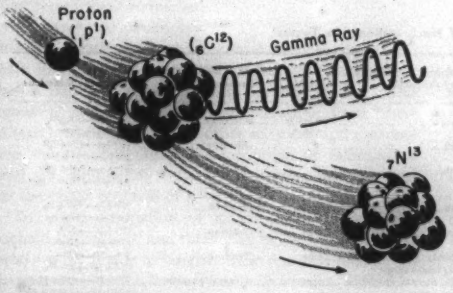
Protons accelerated by high-voltage machines were used to produce the first artificially induced nuclear reactions. Since then studies of proton-induced nuclear reactions such as (p,γ), (p,n), (p,α) have added greatly to the better understanding of nuclear phenomena.



Generally, the

gamma radiation given off by (p,γ) reactions is energetic. Radiation energies as high as 17 million electron volts have been obtained. Nuclear reactions of this type can be used as a source of penetrating gamma radiation to induce still other reactions or for radiographic, medical, or other experimental purposes. Because no material particle is emitted in (p,γ) reactions, the proton energy required to cause the transmutation to take place is a resonance phenomenon and occurs for discrete proton energies. The gamma radiation corresponds to transitions between the energy states of the compound nucleus involved.

Reactions of this type also can result in the formation of a radioactive nucleus as well as the emission of an energetic gamma ray. In fact, when carbon ($_6C^{12}$) is

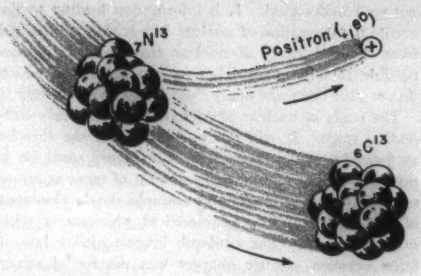


bombarded by protons, gamma rays having energies of about 2.5 million electron volts are emitted. The ($_7N^{13}$) nitrogen nucleus formed in this reaction is radioactive and decays (equation 15) by the emission of 1.2-million-electron-volt positrons into the stable carbon ($_6C^{13}$). The half-life of the radioactive $_7N^{13}$ nucleus is 10 minutes. Hence prompt use of this material, for chemical tracer and other purposes, is necessary inasmuch as at the end of 24 hours only one radioactive atom in 10^{43} of the original sample remains. These two reactions, currently being used in tracer studies, are

$$_6C^{12} + {}_1H^1 \rightarrow {}_7N^{13} + \gamma \qquad (18)$$

$$_7N^{13} \xrightarrow[\text{half-life}]{10\ \text{minutes}} {}_6C^{13} + {}_{+1}e^0 \qquad (19)$$

Reactions of the (p,n) type also are observed and are particularly valuable for the determination of nuclear masses. When this process occurs, the nucleus simply exchanges one of its neutrons for a proton, resulting in the formation of the next highest element of the same mass number as the bombarded substance. Such a process involves a net loss in mass to the nucleus: the neutron mass is greater than that of the proton. Mass or energy must be added to the nucleus to make up for this loss if stability of the same order as the original nucleus is to result. For this reason (p,n) reactions are always endothermic (Q is negative), meaning that the



protons always must have energy greater than a certain amount, called the threshold energy E_p of the reaction (p,n). E_p may be determined by the relationship:

$$E_p = \left(\frac{A+1}{A}\right) Q$$

where A is the mass number of the bombarded nucleus. If the mass of the bombarded nucleus is known, the mass of the product nucleus then can be determined; or conversely, if the mass of the product nucleus is known the bombarded nucleus is determined. Transmutations of the (p,n) type not only lead to the production of radioactive nucleuses, but also afford a convenient and highly accurate method of investigating and studying the mass and energy relationships that enter these reactions.

Transmutations of the (p,α) type also are known. This reaction is usually exothermic because of the high binding of the alpha particle. The probability of occurrence of this reaction is high only when the energy of the bombarding proton is large. Alpha particles are not usually observed because of the experimental difficulty in distinguishing them from protons used in the bombardment. However, the existence of the reaction definitely has been established by examining the radioactive products caused by the (p,α) transmutation. An example of this process is the formation of radioactive fluorine ($_9F^{17}$) by the bombardment of neon nucleuses:

$$_{10}Ne^{20} + {}_1H^1 \rightarrow {}_9F^{17} + {}_2He^4 \qquad (21)$$

$$_9F^{17} \xrightarrow[\text{half-life}]{20\ \text{seconds}} {}_8O^{17} + {}_{+1}e^0 \qquad (22)$$

The resulting radioactive fluorine formed in this reaction decays into oxygen by the emission of positrons.

The investigation of nuclear reactions is obviously complicated. Many reactions may be occurring simultaneously during the bombardment of a target by high-speed particles, for any reaction that is energetically possible has a finite chance of occurrence. It is just this probability feature that specifies the dominant reaction in a given case.

However, the detailed mechanism and nuclear forces that cause one reaction to be preferred to another are

not well understood. It is information leading to the eventual explanation of nuclear secrets that is obtained from detailed study of nuclear reactions. It is now possible to tabulate which reactions occur and which do not, but there are many "why's" to be answered.

The study of nuclear physics is still in the early fact-finding stage. It will not be possible for the theorist to formulate an adequate nuclear theory until he is provided with a considerable amount of more accurate scientific data. Compare, for example, the development of the understanding of electrical phenomena with nuclear science. The coulomb inverse square law of force between electric charges was discovered many years before electricity was put to practical use; in nuclear science we still do not know the law of force that operates between a proton and a neutron. The situation is even more complicated in nuclear investigation in that there is no known method of measuring this force. In electricity it is possible to set up two charged bodies in a mechanical system and to measure the force exerted between them, when they are separated by considerable distances. The action of this force then can be computed for short distances of separation of the charged bodies. In nucleonics analogous experiments are not possible, as the force between the neutron and proton falls off so rapidly with increasing particle separation that measurements of its magnitude for reasonable separations are not feasible. Furthermore, it is not possible to isolate a quantity of neutrons and attach them to a body for measurement purposes as is done in the determinations of the characteristics of electric forces. In nucleonics this does not seem possible because no method yet has been discovered to bring the proton and neutron into sufficiently close proximity and at the same time to measure the force of attraction by mechanical means. One only can accelerate a nuclear particle and use it as a projectile to bombard other particles or nucleuses and to observe what nuclear reactions or other interactions occur. When studies like these are made with sufficient accuracy it may be possible to infer what law of force is required to produce such effects. Scattered experiments of this type, coupled with nuclear reaction data, have indicated that the separation distance between the particles of nuclear physics must be less than 10^{-12} centimeter before the forces of attraction set in. For separations greater than 10^{-12} centimeter, no particular effects other than the coulomb electric forces seem to exist. The greatest value of nuclear reaction studies lies in the fact that detailed examination of the processes that occur enable conclusions to be made concerning the structure of nucleuses and the binding forces.

Table II. Summary of Nuclear-Reaction Types[1]

Reaction Type	Incident Particle	Ejected Particle	Normal Mass Change	Dependence on Energy of Projectile	Yield	Type of Radioactivity Usually Produced	Sample Reactions
(n,γ)	Neutron	Gamma	Positive	Resonance	Virtually 100%	Electron	$Ag^{107}+n \rightarrow Ag^{108}$ $Br^{79}+n \rightarrow Br^{80}$
(n,p)	Neutron	Proton	Slightly positive	Smooth	*	Electron	$N^{14}+n \rightarrow C^{14}+H^1$ $S^{32}+n \rightarrow P^{32}+H^1$
(n,α)	Neutron	Alpha	Slightly positive in light elements; negative in heavy	Smooth	*	Electron	$F^{19}+n \rightarrow N^{16}+He^4$ $Al^{27}+n \rightarrow Na^{24}+He^4$
$(n,2n)$	Neutron	2 Neutrons	Very negative	Smooth	Small	Positron	$N^{14}+n \rightarrow N^{13}+2n$ $P^{31}+n \rightarrow P^{30}+2n$
(p,γ)	Proton	Gamma	Positive	Resonance	Large	Positron	$C^{13}+H^1 \rightarrow N^{14}$ $F^{19}+H^1 \rightarrow Ne^{20}$
(p,n)	Proton	Neutron	Negative	Threshold; smooth increasing with energy	Large	Positron	$B^{11}+H^1 \rightarrow C^{11}+n$ $O^{18}+H^1 \rightarrow F^{18}+n$
(p,α)	Proton	Alpha	Slightly positive in light elements; negative in heavy	Smooth, increasing with proton energy	Large	Generally stable	$F^{19}+H^1 \rightarrow O^{16}+He^4$ $Al^{27}+H^1 \rightarrow Mg^{24}+He^4$
(p,d)	Proton	Deuteron	Very negative	Smooth as above	Small	Only one found	$Be^9+H^1 \rightarrow Be^8+H^2$
(α,n)	Alpha	Neutron	†	Smooth	‡	Positron	$B^{10}+He^4 \rightarrow N^{13}+n$ $Al^{27}+He^4 \rightarrow P^{30}+n$
(α,p)	Alpha	Proton	**	Smooth	‡	Generally stable	$Al^{27}+He^4 \rightarrow Si^{30}+H^1$ $N^{14}+He^4 \rightarrow O^{17}+H^1$
(d,p)	Deuteron	Proton	Always positive	Smooth	‡	Electron	$Na^{23}+H^2 \rightarrow Na^{24}+H^1$ $P^{31}+H^2 \rightarrow P^{32}+H^1$
(d,n)	Deuteron	Neutron	Always positive	Smooth	‡	Positron	$C^{12}+H^2 \rightarrow N^{13}+H^1$ $Be^9+H^2 \rightarrow B^{10}+H^1$
(d,α)	Deuteron	Alpha	Always positive	Smooth	‡	Generally stable	$O^{16}+H^2 \rightarrow N^{14}+He^4$ $Al^{27}+H^2 \rightarrow Mg^{25}+He^4$
(γ,n)	Gamma	Neutron	Always negative	Sharp threshold	Small	Positron	$Be^9+\gamma \rightarrow Be^8+n$ $Br^{81}+\gamma \rightarrow Br^{80}+n$
(γ,p)	Gamma	Proton	Always negative	Sharp threshold	Small	Only observed for deuteron	$H^2+\gamma \rightarrow n+H^1$

* Large for light elements; escaping barrier to consider. † Slightly negative in light elements; positive in heavy.
** Slightly positive except some light elements. ‡ Large for elements where barrier penetration is easy.

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The Patent Question

L. A. HAWKINS
MEMBER AIEE

Does patent consciousness interfere with co-operation between industrial and university research laboratories? The author takes the stand that our patent system, by protecting the inventor, opens the door to the free interchange of ideas which are so necessary to rapid scientific progress. This is one viewpoint on an important and controversial topic.

ALTHOUGH our patent system is among the older of our national institutions, there still appear to be misunderstandings concerning it which are not confined to the less educated portion of our public.

A recent meeting of scientists brought forth an implied criticism of our patent system in the statement, which seemed to meet acceptance with many, that overconcern for patents caused many industrialists to draw an iron curtain around their research laboratories, thereby excluding from their research staffs the visits of other scientists and preventing the mutually helpful interchange of information and the stimulating exchange of ideas which are vital to the rapid progress of scientific knowledge.

In every occupation of mankind there are shortsighted individuals, and there may be some industrialists who would prefer to confine their research men in an ivory tower, but it is strange that such a policy should be blamed on the very institution which makes such a policy needless and foolish.

If we had no patent system, then indeed it would be necessary for an industrialist, if he had a research laboratory, to make the hard choice between free scientific exchange, with the practical certainty of frequent and immediate financial loss, and scientific isolation, with the long-range certainty of ultimate sterility. Or perhaps he might attempt a compromise, with the probability of incurring both kinds of loss. Under such conditions, probably very few companies would start or long maintain a research laboratory. It would need a farsighted, courageous, and patriotic industrialist with a long pocketbook to undertake research under such conditions. Such a man, fully realizing that in the long run industrial progress is dependent on scientific research, and that, if there were no industrial research in the United States, his whole industry and his company along with it would suffer mortally from competition of other countries where industrial research conditions were more favorable, would decide that he must support some research, even in the face of certain immediate loss in domestic competition.

Our patent system obviates the necessity for such hard decisions. It makes it possible to operate a research laboratory with doors wide open to the stimulating visits of outside scientists, without loss and with the great benefit of the mutual fertilization of ideas which such visits produce.

Patenting an invention protects the inventor or his employer from the gratuitous pirating of its benefits by others. If others wish to share in those benefits, they may be made to share in its cost, through reasonable royalty payments. The effect on the research man in industry is that he is free to welcome fellow scientists from universities or other industrial laboratories, exchange information with them, discuss experiments, compare ideas, and argue on theoretical matters.

The prime function of a research laboratory is to seek new scientific facts. A newly-discovered fact may suggest a patentable application or new material, but the invention is incidental to the scientific work which claims the research man's main interest and which is not patentable. If there were no patent system, not even that scientific work could be discussed freely with fellow scientists for their mere presence in the laboratory would involve possible loss, through their observing and disclosing, quite possibly in all innocence, to its competitors practical developments in progress in the laboratory. Without a patent system, the only safeguard for discovery and its praetical applications would be complete secrecy. Furthermore, no industrial research laboratory could welcome visitors safely or send its men to meetings of scientific societies except in the role of sponges, permitted only to absorb in silence.

With our patent system the industrial scientist may enjoy all the freedom to give and take which is possessed by his peers in the universities. The only restraint on his tongue or pen is that, if his work suggests a possible patentable practical application, his first disclosure should be to his patent attorney; and, if the latter thinks a patent application advisable, reasonable time should be given to prepare the necessary papers before further disclosure is made. If he observes this trifling and temporary restraint, the industrial scientist may enjoy to the full his intercourse with his fellows, free and unconstrained, and the institution he serves may reap the undoubted benefit such intercourse yields.

Full text of the article, "Does Patent Consciousness Interfere With Co-operation Between Industrial and University Research Laboratories?", published in *Science* (Washington, D. C.), volume 2726, March 28, 1947, pages 326–7.

L. A. Hawkins is consultant, research laboratory, General Electric Company, Schenectady, N. Y.

A few industrialists, and possibly a very few directors of research, even yet may not be fully awake to the opportunity of free scientific exchange in safety which our patent system makes possible. The increasing frequency of exchange of visits between industrial laboratories, as well as between these and the universities, shows that the number of those who have not seen the light yet is small and is growing smaller. With those few, to blame the patent system rather than their individual blindness for their shortsighted policy is surely an error.

No human institution is perfect, and our patent system is a human institution. Indeed, the advisory committee appointed by President Roosevelt has recommended certain minor changes in it, which informed opinion quite generally believes might be adopted with advantage by the Congress, but the basic principles of that system the committee found to be sound.

Their finding seems supported by the record. With that system in force, the United States has achieved the greatest fertility in invention and the greatest industrial progress the world yet has seen. Many a small manufacturer, protected by his patent, has built up a highly prosperous business with some meritorious specialty. Manufacturers large and small, to the number of more than 2,500, relying on the patent protection they could obtain for applications of research, have founded and profitably are operating research laboratories and thereby helping in the advancement of their industries, the national economy, and scientific knowledge. As for the scientist himself, if he wishes to take advantage of the facilities offered by an industrial laboratory for research in his special field of interest, and if he finds that he may do so with no sacrifice of his precious privilege of free discussion with his fellow scientists, whatever their associations may be, he should give thanks where thanks are due—to our patent system.

Magnetic Sound-on-Film

MARVIN CAMRAS
ASSOCIATE AIEE

Simplicity of equipment required and adaptability of the process to 8-millimeter as well as 16- and 35-millimeter film are among the advantages claimed for magnetic recording of sound on motion picture film. Experimentally converted conventional projectors that can be used as recorders also are described.

THE CHIEF ADVANTAGE of magnetic recording of sound on motion picture film is its extreme flexibility. Magnetic sound promises not only to add flexibility to the present optical sound on film systems, but also to open new fields where sound on film was not previously possible, or where it was not sufficiently versatile.

Examples of magnetic sound films which have been used successfully are illustrated in Figure 1. Some of these are for the "double" system of sound on film, where sound is recorded on a separate film which is run in synchronism with the picture film. Others are for the "single" system, where both picture and sound track are on the same film.

The magnetic track is a layer of magnetizable material which is bonded permanently into the film stock. The track can be deposited over the whole film area, or in place of the conventional optical track, or in addition to the optical track. A typical magnetic track is 0.0005-inch thick, and anywhere from 0.016- to 1.00-inch wide.

This article is adapted from papers presented before the Society of Motion Picture Engineers and the Acoustical Society of America.

Marvin Camras is research physicist, Armour Research Foundation, Chicago, Ill.

RECORDING METHOD

A record is made on the track by magnetizing it according to the sound that is to be recorded. One method for accomplishing this is shown in Figure 6. The film is passed over a flywheel stabilizer against which a magnetic head is pressed. Recording is done by the flux in a narrow "air" gap in the magnetic head. As the film passes the head, each element of the track is magnetized permanently by the flux in the head at the time that element is in the "air" gap. To play the record, the same magnetic head may be used as a pickup by connecting it to the input of an amplifier. Flux variations in the magnetic track running past the head induce a voltage which is amplified and converted into sound by a loud-speaker.

While the magnetic record is quite permanent and can be played any number of times, it can be erased by a high-frequency field. The track is then ready for a new

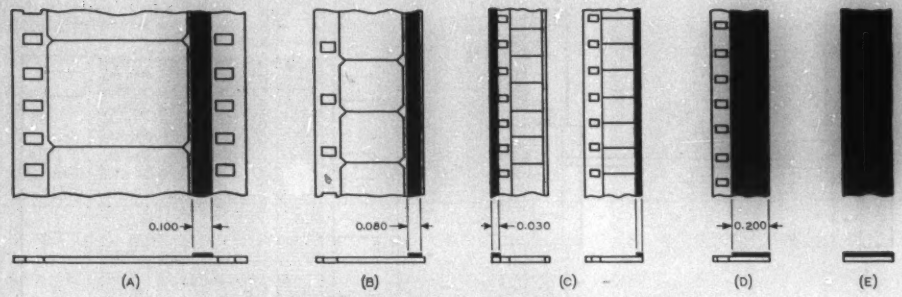

Figure 1. Magnetic films and tapes (dimensions indicated are in inches)

A, B, C—35-, 16-, and 8-millimeter picture films, respectively, with magnetic sound tracks
D—8-millimeter film with full width track for synchronized work
E—Coated plastic or paper tape for nonsynchronized work

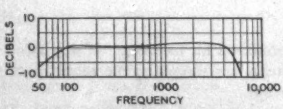

Figure 2. Over-all response of 16-millimeter system

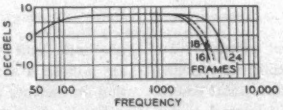

Figure 3. Over-all response of 8-millimeter system

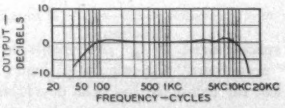

Figure 4. Over-all frequency response of 35-millimeter magnetic recording system

record. A block diagram of a typical erase-record-playback arrangement is shown in Figure 21. With the switch in position *A*, as shown, a high intensity 40-kc current flows through the head and sets up a field which erases the record. Position *B* is for recording. Sound picked up by the microphone is amplified, equalized, and fed into the head. Some current from the 40-kc oscillator is mixed with the audio frequencies to improve the linearity of recording. Position *C* of the switch is for playback. The signal is picked up by the head, equalized, amplified, and fed to the speaker.

ADVANTAGES

In general, magnetic sound-on-film has the following advantages over optical sound:

1. It can be erased for correction purposes, or for reuse of the material.
2. No developing or other processing is required, and the record can be played immediately after recording.
3. The record (not merely the recording signal) can be monitored as it is being made.
4. Equipment is simpler and less expensive.
5. Open apparatus (no light-tight boxes required).
6. Less serious distortion caused by overmodulation.
7. The track can be added to the picture after it is developed, edited, or printed.
8. The track can be placed outside sprockets for adding sound to present silent films.
9. Good quality is obtained at 16-millimeter and 8-millimeter film speeds with limited track width.
10. Multiple tracks can be made simultaneously or in succession.

The magnetic sound-on-film system is especially well suited for post-synchronization work, where the dialogue is recorded after the picture has been made and must be

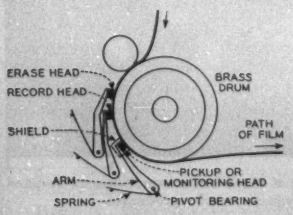

Figure 5. Magnetic head assembly

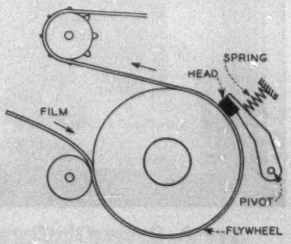

Figure 6. Recording assembly for magnetic sound system

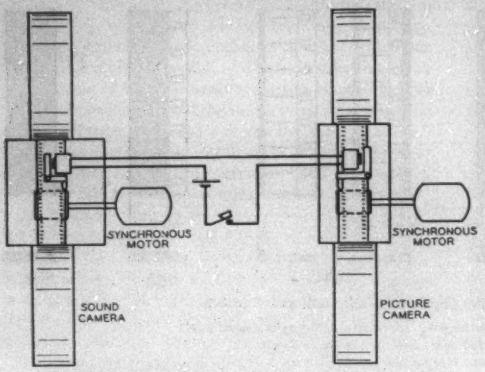

Figure 7. Synchronization of sound and picture cameras

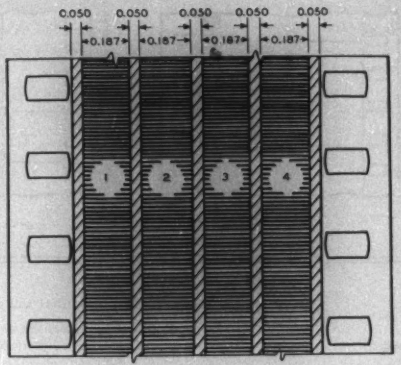

Figure 8. Four-channel 35-millimeter sound system

synchronized to lip movements in the picture. To "post-record" the original dialogue is difficult enough, but the technique has been developed to a point where even a foreign language can be recorded instead of the original sound. By a proper choice of words and phrases, the translation can be done so skillfully that it is difficult to detect.[1]

Post-synchronization generally is done on short portions of film. Many attempts must be made before a perfect take is secured, and a large volume of film is wasted with conventional methods; also, the film cannot be "audited" until after developing. With the magnetic recording system, a film of the type shown in Figure 1 is made into a large loop. While the picture is being projected, the erase and record heads are active. Each time the appropriate sequence is flashed on the screen, the artist attempts to talk in synchronism with the picture. As soon as a successful recording appears to be made, the erase and record heads are switched off, and the playback head is connected for listening. If any flaws are noticed, the switches are thrown to the record position for another attempt.

Rerecording of magnetic sound-on-film for copies can be done at the same time as the picture is being run through a printer, so that no additional operation is necessary. The magnetic sound can be converted to optical sound for projection in conventional machines.

MAGNETIC MATERIAL REQUIREMENTS

Requirements of the magnetic material to be used for the track are rather severe. For good low-frequency response and maximum output it should have a high remanence. For good high-frequency response, and for stability and permanence, it must have high coercive force. These characteristics should be developed at relatively low fields; otherwise the material is difficult to magnetize and almost impossible to erase. For a low noise level the particle size must be small so that a smooth

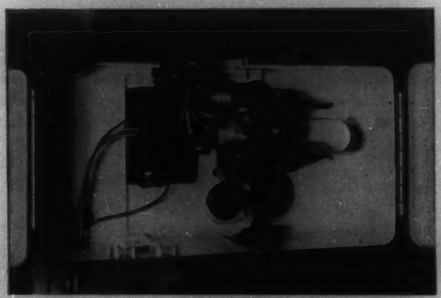

Figure 9. Close-up of 35-millimeter sound head

Figure 10. Close-up of 16-millimeter sound projector modified for magnetic sound reproduction

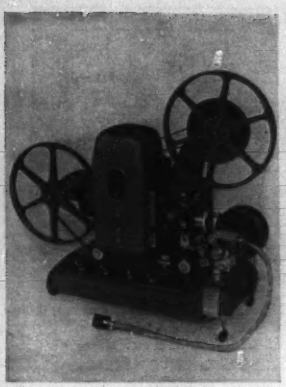

Figure 11. An 8-millimeter magnetic sound projector

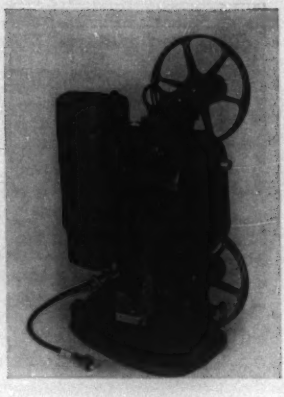

Figure 12. Adapter plate mounted on 8-millimeter projector

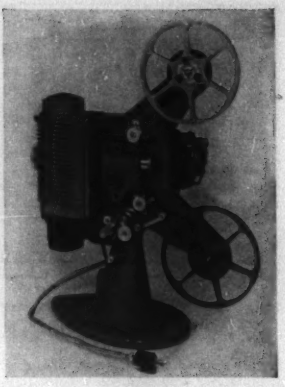

Figure 13. Converted 8-millimeter silent projector

homogeneous track is formed. Typical response curves are shown in Figures 2, 3, and 4.

One of the developments which has made high quality magnetic sound-on-film possible is a new magnetic material which meets the foregoing requirements. Characteristics of a track made of this material are

Particle size	less than one micron
Remanence	$B_r = 900$ gauss
Coercive force	$H_c = 350$ oersteds
Saturation field (approximately)	$H = 1{,}000$ oersteds

Photographic processing does not harm the magnetic properties, and the track is durable enough to last for the life of the film.

APPLICATIONS

Although there are an unlimited number of variations and applications on magnetic sound-on-film, it is convenient to group them in three main classes:

1. High-fidelity professional-type 35-millimeter equipment.
2. Semiprofessional and high grade amateur 16-millimeter equipment.
3. Amateur 8-millimeter equipment.

These will be considered separately, noting that there is some overlapping, depending on the specific uses.

35-MILLIMETER SOUND-ON-FILM

A close-up view of a laboratory model of the 35-millimeter sound-on-film system is shown in Figure 9. This sound equipment is designed for the "double system" where the picture is taken with a separate picture camera. Synchronization may be carried out by the use of a pair of relays to mark the sound film and the picture film as shown in Figure 7. Standard 35-millimeter parts are used for the mechanical section, and the film is driven at the 24-frame sound-speed of 90 feet per minute. The magnetic film is pulled from the upper magazine into a Simplex picture head, through a Motiograph soundhead, and into the lower magazine. As shown in Figure 9, the exciter lamp, lens system, and photoelectric cell have

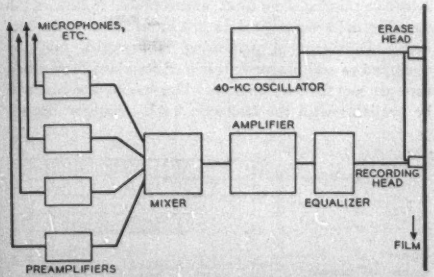

Figure 14. Magnetic sound-on-film recording system

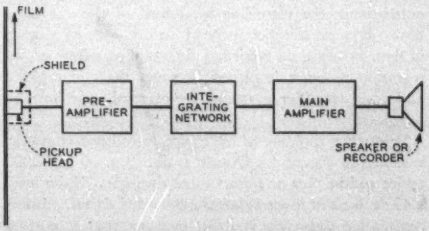

Figure 15. Magnetic sound-on-film playback system

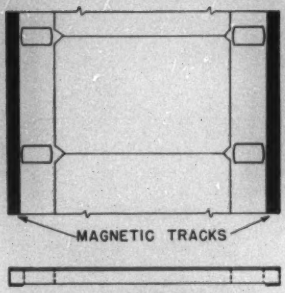

Figure 16. Standard 16-millimeter film with two magnetic tracks

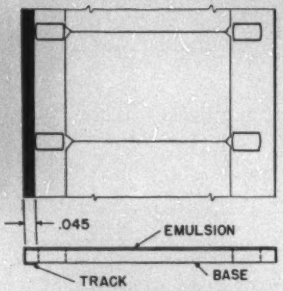

Figure 17. Standard 16-millimeter film with single magnetic track

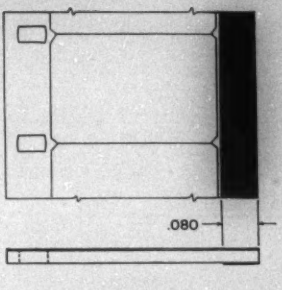

Figure 18. Sixteen-millimeter sound film with magnetic track

been removed from the soundhead, and a plate carrying three magnetic heads has been installed in their place.

Figure 5 gives details of the magnetic head assembly. The film goes past a hold-down roll which insures good contact with the brass flywheel drum. An erase head removes any previous record from the film, and a record then is put on by the record head. The track can be monitored while it is being made; for this purpose a pickup or monitoring head is installed a short distance below the record head and shielded from it. A light spring pressure is enough to allow the head to make good contact with the film. Splices are passed easily by this arrangement.

Dimensions of the film tracks are shown in Figure 8. Four or more tracks can be accommodated on a 35-millimeter film, although only one normally is used. The additional tracks can be used for:

1. Sterophonic recordings with a control track.
2. Additional recordings (for economy of space in sound-on-film libraries).
3. Simultaneous recording of important "takes" from microphones or instruments in different locations.
4. Editing and rearranging, where background music, sound effects, and control signals can be put on the additional tracks and later combined when a satisfactory arrangement is obtained.

The amplifier system for recording is shown in Figure 14, and the playback arrangement is indicated in Figure 15. The recording equalizer is adjusted to give the response shown in Figure 19, which compensates for characteristics of the recording head and of the magnetic film. Because the pickup head detects rate of change of flux, rather than recorded flux, an equalizer or integrating network is placed between the preamplifier and main amplifier to restore the original wave form on playback.

Frequency response of the entire 35-millimeter system is shown in Figure 4. Output is flat from 50 to 12,000 cycles within plus or minus three decibels. Noise level is 45 decibels or more below the recorded signal. Intermodulation distortion is about four per cent at normal recording levels.

16-MILLIMETER SOUND-ON-FILM

Optical sound films of the 16-millimeter size are available for educational and entertainment use; but before the introduction of magnetic sound there was no satisfactory way for the amateur to make his own sound films except with equipment and methods that required professional ability in operating skill and that were high in cost.

With magnetic recording, a projector equipped for erasing, recording, and playback is no more complicated than the usual 16-millimeter optical sound projector. A 16-millimeter sound projector which has been modified for magnetic sound is shown in Figure 10. It uses standard 16-millimeter film to which magnetic tracks are added as indicated in Figures 16, 17, or 18. With a projector of this type, the sound is put on after the film has been developed and edited. Instead of making photographic titles, the amateur can narrate his pictures after he has edited them. If he wishes to reassemble his sequences or to change his story he is free to do so, for the track can be erased and reworded.

Applications in the educational field are especially promising because the teacher easily can make sound films of subjects which are of special interest to him and which he may treat in his own style. Uses in industry and for advertising are apparent. A sound track can be added to existing silent films, as it is placed outside of the sprocket holes where it does not interfere with the picture. Photographic processing laboratories may be equipped to add magnetic tracks to standard films when they are sent for development. Unexposed film also will be available with the magnetic track. Satisfactory re-

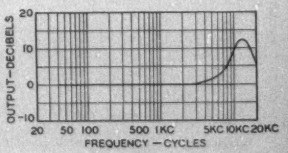

Figure 19. Response of recording equalizer

sults are obtained at the silent speed of 16 frames (4.8 inches per second) as well as at standard sound speed of 24 frames (7.2 inches per second).

With a modified camera, sound can be recorded on the film as the picture is taken. This is more difficult than "post-recording" because special precautions must be observed to keep the camera noise and other undesirable sounds from being picked up. One way of obtaining "direct" sound without a special camera is to record it on an ordinary recording machine (magnetic or otherwise) while taking the picture. After the film is finished, the original recording is rerecorded on the film. Several attempts may have to be made before perfect synchronism is obtained.

The electrical system used with the 16-millimeter projector is indicated in Figure 21. A typical over-all frequency response curve given by Figure 2 is flat within plus or minus three decibels from 70 to 5,000 cycles per second. With care, the response can be held flat to 7,000 or 8,000 cycles at the 24-frame speed. Signal-to-noise ratio is above 40 decibels, and harmonic distortion below three per cent.

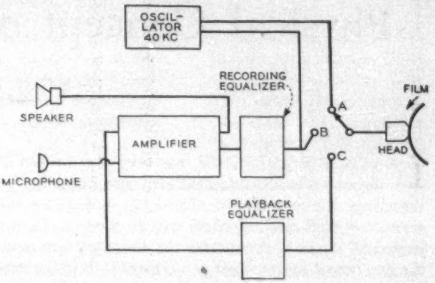

Figure 21. Electrical system used with a 16-millimeter projection

Table I. Sound Storage Index for Films

Type of Projection	Frames Per Second	Film Speed, Inches Per Second	Track Width, Mils	Sound Storage Index = Speed × Width	Relative Per Cent Rating
35 mm sound	24	18	100	1,800	100
16 mm sound	24	7.2	80	576	31
8 mm sound	24	3.6	30	108	6
8 mm "silent" (1)	18	2.7	30	81	4½
8 mm silent (2)	16	2.4	30	72	4

8-MILLIMETER SOUND-ON-FILM

Eight-millimeter film runs so slowly and has such limited space that attempts at optical sound recording have given discouraging results. Table I compares the room available for a sound track on different films. The sound storage index takes into account both the speed and the track width. If 35-millimeter film is given a rating of 100 per cent, then 8-millimeter film has a rating of only about four to six per cent.

Experiments with the magnetic method have indicated that excellent results for amateur work can be obtained with 0.030-inch-wide magnetic tracks located as shown in Figure 1. Some conventional 8-millimeter projectors that were adapted experimentally for magnetic recording are shown in Figures 11, 12, and 13. Although the film transport systems differ considerably, the same electrical system as shown in Figure 20 is used in each case.

It has been suggested that an 18-frame projection speed be standardized for 8-millimeter film projection of pictures photographed at 16 frames per second. Many amateurs now project their silent films at this slightly higher speed because flicker is reduced and action is more dramatic. For sound pictures, the frequency characteristic is improved by the increase in velocity.

Figure 3 gives the frequency response of an 8-millimeter system for different film speeds. The response compares favorably with that of small table model radios, and is adequate for most amateur work. Noise level and distortion are about the same as with the 16-millimeter system.

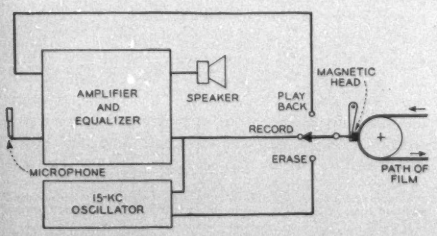

Figure 20. Magnetic sound-on-film recording system

CONCLUSIONS

Magnetic sound-on-film is a new tool for the professional sound-man. It is more versatile and economical than optical sound. The 16-millimeter magnetic sound equipment is especially suited for educational, industrial, and advanced amateur uses. Full length productions, which never would be made with present methods because of time and cost, can be "home-made" with hardly more trouble than silent pictures. The 8-millimeter magnetic sound projector brings sound on film within the reach of every amateur 8-millimeter enthusiast.

REFERENCE

1. Some Special Problems of Post-Synchronization Mixing, T. Lawrence. *Journal* Society of Motion Picture Engineers (New York, N. Y.), volume 48, April 1947, pages 317–23.

Physical Concept of Leakage Reactance

JOHN H. KUHLMANN
MEMBER AIEE

LEAKAGE REACTANCE has been the subject of discussion in the technical literature from time to time since the adoption of alternating current for the generation and utilization of electric power. In the beginning it was customary for the designer to estimate the number of leakage lines per ampere inch of the embedded portion and end connections of the windings and multiply these by the respective lengths to obtain the reactance. Early writers treated this subject under the title of magnetic dispersion and took account of its effect through the use of a leakage coefficient. About the leakage coefficient R. E. Hellmund writes:

> The chief reason for determining this value is, however, the fact that it fixes directly the excellence of a motor in almost every respect and, therefore, the values obtained for this factor form a direct means for determining the relative merits of various designs. If properly designed a motor will always be better the smaller the leakage coefficient. The leakage coefficient no matter how it is defined is always the ratio between the effects of the leakage field and the main field.

Later writers expressed the effect of the leakage flux as a reactance. Regarding the importance of the leakage reactance upon electric machinery characteristics C. A. Nickle states:

> Tell me the reactances, and I'll tell you the behavior of the machine under any condition.

This article is an attempt to present a nonmathematical discussion of the general concept of leakage reactance as it exists in the transformer, the induction motor, the synchronous machine, and the d-c machine.

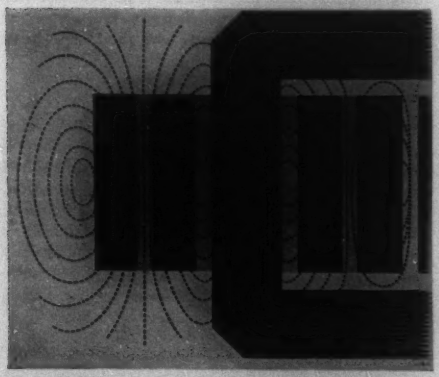

Figure 1. Leakage flux in transformer core

TRANSFORMER

In the transformer the primary winding (that winding which is connected to the line and provides the exciting magnetomotive force) produces a flux in the magnetic core. If the secondary winding is wound on the same core element as the primary, most of the flux produced by the exciting winding also will interlink the secondary winding. It is impossible to arrange the windings or to design the core so that all of the primary winding flux will pass through the core. The part of the primary flux which does not pass through the core but takes the path between the two windings and returns through the primary coil and the entire space surrounding the coil is called the primary leakage flux ϕ_{L1}. When a load is connected to the secondary winding, the resulting current produces a magnetomotive force which is opposed to the primary. The resulting secondary flux takes the path between the two windings and returns through the secondary coil and the core. This is called the secondary leakage flux ϕ_{L2}. The flux in the core and the leakage flux in primary and secondary coils are shown in Figure 1 for a single-phase core-type transformer. For other core and winding arrangements similar leakage paths will result. Leakage flux calculations usually are made on the assumption that these fluxes exist independently. In reality there is only one resultant flux and the leakage fluxes appear as distortions of the total flux. The leakage fluxes of primary and secondary windings which are interlinked with one winding only do not contribute to the output of the transformer. However, they do induce voltages in the respective windings which must be overcome by a component of the impressed voltage.

In the vector diagram, Figure 2, the flux in the core, produced by the primary magnetizing current, is responsible for the induced voltages E_1 and E_2 in primary and secondary winding. The secondary leakage flux ϕ_{L2} is in phase with the secondary current and induces the voltage E_{L2} in the secondary winding which is 90 degrees out of phase with the current I_2. The secondary induced voltage is then the vector sum of the secondary terminal voltage plus the resistance drop and plus a component to balance the secondary leakage flux volt-

Full text of miscellaneous paper 47-207, "Physical Concept of Leakage Reactance," presented at the AIEE Middle Eastern District meeting, Dayton, Ohio, September 23–25, 1947.

John H. Kuhlmann is professor of electrical design at the University of Minnesota, Minneapolis, Minn.

age E_{L2}. The primary terminal voltage must be equal to the vector sum of voltage components to overcome the induced voltage, the resistance drop, and the primary leakage voltage E_{L1}. As Figure 1 shows, primary and secondary leakage flux paths are in air for which the permeability is constant and equal to one. The leakage flux will vary directly with the current producing it and will be in phase with it. The inductance of a winding is defined as the interlinkages between the turns and the flux per unit of current producing it. The leakage flux per unit of current producing it times the turns with which it is interlinked multiplied by $2\pi f \times 10^{-8}$ is, therefore, a reactance and is called the leakage reactance of the winding. The voltage components in the primary and secondary windings to overcome the leakage flux voltages E_{L1} and E_{L2} then can be replaced by I_1X_{L1} and I_2X_{L2}, the primary and secondary leakage reactance drops respectively.

A brief review of the causes and effects of leakage reactances in various electric equipment, this article compiles essential information which normally is scattered throughout engineering textbooks or omitted completely.

INDUCTION MOTOR

The induction motor is basically a transformer producing mechanical energy. Unlike the transformer, the primary and secondary windings are on two distinct winding elements separated from each other by an air gap. The magnetic circuit cannot be designed so that all of the flux produced by the magnetomotive force of the windings will interlink both. The flux interlinked only with the stator winding is called the stator leakage flux and the flux interlinked only with the rotor winding is called the rotor leakage flux. Because of the more complicated arrangement of the windings in an induction motor, as compared with a transformer, the leakage paths take on a more complicated picture. Figure 3 shows a portion of the stator and rotor of a motor with 3-phase stator winding having one slot per pole per phase. The resultant magnetomotive force of the three phases produces the flux shown by the solid lines, which crosses the air gap and is interlinked with the rotor winding. This flux produces the useful output of the motor. The stator flux crossing the slot is called the slot leakage flux, and that crossing the tooth tips, the tooth tip leakage flux. There is also a flux surrounding the coil end connections, that is, that portion of the coil which lies outside of the core. This is called the end-connection

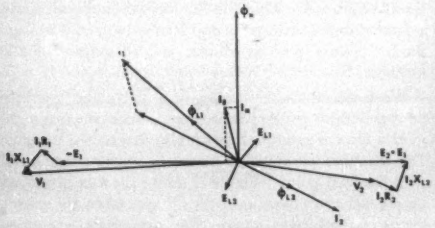

Figure 2. Vector diagram for transformer

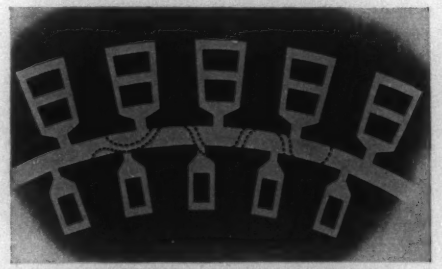

Figure 4. Induction motor tooth tip leakage flux

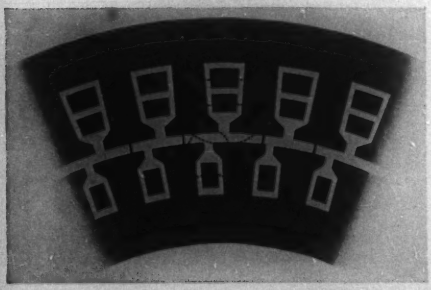

Figure 3. Induction motor slot leakage flux

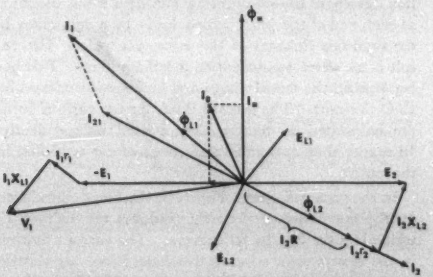

Figure 5. Vector diagram for induction motor

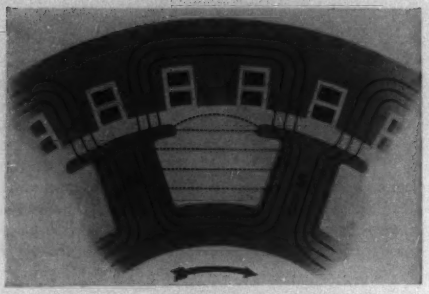

Figure 6. Field pole flux in a synchronous machine

leakage flux. Similar leakage flux paths exist for the rotor winding. For a stator winding with more than one slot per pole per phase, the tooth tip leakage flux embraces the slots of a phase belt and takes the path shown in Figure 4. It then is called the zigzag leakage flux.

When the rotor has a polyphase winding, as in the wound-rotor induction motor, another leakage flux is present. The windings of stator and rotor may have different distribution and the rotor can assume positions where the phase belts of rotor and stator windings do not coincide. Because of the displacement of the two windings, the fields setup is different for any given pole axis and will produce positive and negative flux loops in the air gap of the same pole face. The resultant flux linkages with the rotor winding produce voltages which cancel out in the rotor. In the stator, however, because of the relative position of the winding and the flux distribution, a voltage is induced in every respect similar to a self-induced voltage. This effect first was recognized by Professor Adams and called "belt leakage." Subsequent investigators have referred to it as differential leakage.

When a rotor has a squirrel cage winding the bars do not always pass through the rotor core parallel to the shaft but are twisted or skewed. For skewed bars the flux density of the resultant air gap field is not the same at each end of the bars, which leads to a reduction in the total flux linkages of the rotor per pole. The result is an effect equivalent to a leakage flux. This has been called the skew leakage and first was introduced by C. G. Veinott. The leakage fluxes for the various paths are calculated as though they existed independently. In reality they appear as distortions of the total flux in the motor.

In the vector diagram, Figure 5, the flux ϕ_m produced by the magnetizing current I_m induces the voltage E_2 which lags the flux by 90 degrees. The current flowing in the closed rotor winding resulting from this voltage produces the rotor leakage flux ϕ_{L2}, which is in phase with I_2. The rate of change of the leakage flux interlinked with the rotor winding induces the voltage E_{L2}, which lags the current I_2 by 90 degrees. The rotor induced voltage E_2 is made up of three components, the resistance drop through the equivalent load resistance, the resistance drop of the rotor winding, and a component of voltage to overcome the voltage resulting from the leakage flux E_{L2}. The vector diagram shows that the voltage components to balance the voltage generated by the stator and rotor leakage fluxes lead their respective currents by 90 degrees. They are in every respect equivalent to an inductive reactance drop so that E_{L1} and E_{L2} can be replaced by I_1X_{L1} and I_2X_{L2}, the stator and rotor leakage reactance drops respectively.

SYNCHRONOUS MACHINES

The synchronous machine has the same type of winding and construction of the armature as the stator of the induction motor. The field structure is either of the salient pole type of construction or of the cylindrical rotor distributed winding type used for turbo-type generators. Figure 6 shows two poles of a salient pole synchronous machine with the field winding only excited. The obvious purpose of the designer is to construct the magnetic circuit so that all the flux produced by the magnetomotive force of the field winding will cross the air gap and link with the armature conductors. This is not possible to attain as some flux will follow the dotted lines in Figure 6. This flux has its path in the air space surrounding adjacent poles and is called the field leakage flux. It does not contribute to the output of the machine.

When the armature winding of a polyphase synchronous generator is carrying current, a resultant magnetomotive force is produced which also acts on the air gap. The resultant air gap flux travels at synchronous speed with the field poles. Figure 7 shows the flux produced by the armature current in the air gap when the power factor of the load is unity. The axis of the armature

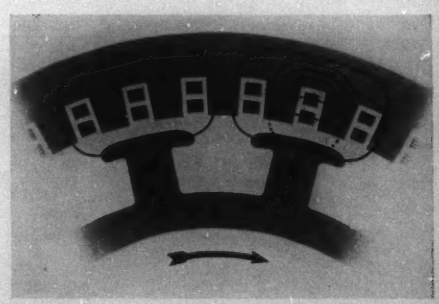

Figure 7. Slot leakage flux in a synchronous machine

flux is in the interpolar space for unity power factor and in the pole axis for zero power factor. The armature flux that crosses the air gap reacts on the field flux, which effect is called armature reaction. That flux produced by the armature magnetomotive force that does not cross the air gap but is interlinked with the armature winding only is called the armature leakage flux. The total armature leakage flux is divided into components very much the same as is done for the induction motor stator already discussed. The vector diagram, Figure 8, shows these fluxes and the resulting voltages for an inductive load. To maintain the terminal voltage V, the generator must have an induced voltage E large enough to overcome the resistance drop and the loss in voltage resulting from the armature leakage flux and armature reaction. The armature leakage flux is in phase with the armature current and because it is an alternating flux induces a voltage E_L which lags the current by 90 degrees. This voltage must be balanced by an induced voltage from the main field. The main armature field crossing the air gap is resolved into two components as proposed by Blondel. The flux ϕ_q in the quadrature axis produces the voltage E_q, the component ϕ_d in the direct axis is responsible for the voltage E_d. The armature leakage flux varies directly with the armature current because the flux paths are in air for which the permeability is constant. The voltage drop caused by the leakage flux of the armature, therefore, can be replaced by an inductive reactance drop which leads the current producing it by 90 degrees. In the vector diagram E_L then can be replaced by IX_L, where X_L is $2\pi f$ times the flux per unit of current and the turns multiplied by 10^{-8}. In the vector diagrams for the induction motor and for the synchronous machine all values are per phase.

D-C MACHINES

In the d-c machine the flux produced by the armature magnetomotive force that crosses the air gap reacts upon the field pole flux to produce distortion very much the same as explained for the synchronous machine. This effect is called armature reaction and gives rise to a loss in voltage at the generator terminals. The leakage flux of the armature winding under the main poles, that is, that portion of the armature flux that does not cross the air gap but is interlinked with the armature winding only induces no voltage in the armature winding because it is produced by a constant direct current. In the interpolar space, however, the current in the armature coils must change from a constant value in one direction to the same value in the opposite direction during the time of commutation. The flux produced by the changing current in the armature coils in the interpolar space is interlinked with the turns producing it. It is not coupled with any other winding and is, therefore, a leakage flux. The voltage induced in the armature winding by this flux is a self-induced voltage and is called the armature leakage reactance voltage. This armature leakage flux generally is divided for purposes of calculation into the slot leakage flux, the tooth tip leakage flux, and the end-connection leakage flux. This armature leakage reactance voltage has a pronounced effect upon commutation and must be neutralized by an equal and opposite voltage. This is done in the modern generator and motor by means of the commutating pole.

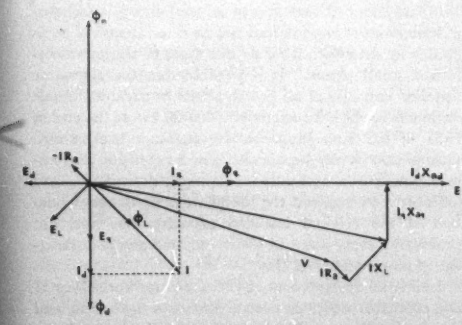

Figure 8. Vector diagram for a synchronous machine

CONCLUSIONS

It has been shown that in every magnetic circuit linking more than one winding there is always some flux that follows local paths and does not link both windings; this is called the leakage flux. If this leakage flux is an alternating or changing flux, it induces a voltage in the winding with which it is interlinked which must be overcome by the line voltage. The leakage flux paths are in air or in magnetic circuits of low saturation so that the flux is directly proportional to the current. Leakage reactance is, therefore, the leakage flux per unit of current times the turns with which it is interlinked multiplied by $2\pi f \times 10^{-8}$. If the permeability of the leakage flux path is constant, the leakage reactance also will be constant. The leakage reactance multiplied by the current is called the reactance drop in the winding; it leads the current in time phase by 90 degrees.

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The Power Industry in China

C. H. CHEN Y. S. SUN

DEVELOPMENT of the electric power industry in China is a rather slow process. In 1936, the consumption of electric energy per capita was only about 4 kilowatt-hours. Industrial development of the country, as well as the living standard of its people, is largely dependent upon a cheap and abundant supply of electricity. Therefore, China is sparing no effort in building up its electric power industry at once.

It was not until 1928, when the National Construction Commission was established, that any significant progress was made in the power industry in China. The National Construction Commission as a governmental organization enacted various laws, rules, and regulations, and effected many improvements on the existing electrical utilities. Many provincial and city governments followed suit to expand and improve the electrical companies in their localities, as did most of the privately-owned small plants. It is possible that the aggregate installed capacity of all power plants owned by Chinese nationals could have exceeded 500,000 kw at the end of 1937, if the Sino–Japanese war had not broken out. Occupation by the Japanese stopped expansion and improvement, and, in addition, damage, destruction, and maloperation reduced the useful capacity to about one-half of the original installed capacity. As a result, practically every place in China suffered an acute shortage of power after *V-J* Day.

Industrial development in China before World War II was concentrated in the coastal areas and the middle and the lower Yangtze River districts. The interior was

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C. H. Chen is director and Y. S. Sun is engineer of the Electricity Administration, National Resources Commission, China. Both are members of the Chinese Institute of Electrical Engineers.

developed little, and included provinces as large in area as Germany or France without a single kilowatt. Because over 90 per cent of the capacity was concentrated along the coast, very little power capacity was left in free China after the Japanese occupation of the coastal section.

THE WARTIME POWER INDUSTRY

After the outbreak of the war in July 1937 the Japanese advance was rapid and the Chinese governmental organizations retreated from the coast, partly to Chungking and partly to Hankow. Many small factories evacuated coastal cities and rebuilt their works around the governmental centers thereby creating a difficult power supply problem.

Early in 1938 the National Construction Commission was amalgamated with the National Resources Commission which was, and still is, entrusted with the task of developing the power industry on a national scale. The National Resources Commission was quite aware of the importance of an adequate power supply for war production and for raising the living standard, and new power plants were planned and constructed, with new generating equipment which was ordered from abroad. Loss of seaports made transportation difficult, and many units, totaling about 15,000 kw, had to be reshipped to French Indo-China and shipped from there by rail. Of these units only a little more than 4,000-kw capacity arrived at Kunming. The rest were taken by the Japanese when they landed at Haiphong in 1940.

A great deal of effort was expended in dismantling generating equipment from coastal cities. It was with great difficulty that more than 5,000 tons of equipment were shipped to interior provinces, among which were steam turbines, steam engines, Diesel engines, and gas engines with capacity from less than 100 to a few thousand kw. Though this figure may be insignificant in the United States, in view of the fact that the task was done in the midst of disorder without modern facilities, it was a great achievement. Dismantled equipment was old and small, and sometimes not in serviceable condition, but it served as a foundation for nearly 20 new power plants widely scattered in the interior of China. In addition to the 15,000-kw capacity mentioned previously, another 5,000 kw were ordered from England and 30,000 kw from the United States. Importation had to be through seaports in India from where the material was shipped either by airplanes or by trucks, neither of which were suitable for transportation of the machinery, especially when military shipments had top priority. Less than five per cent of the equipment was brought in successfully and installed for service, most of the equipment since having been reshipped to Shanghai.

Without new equipment, extension of power production was handicapped greatly. But the need of power was so urgent that all facilities, when once put into service, soon were overloaded heavily. Whatever available equipment, whether economical or in useable condition, was repaired and installed. For example, one plant was equipped first with two 25-year-old steam engine sets in 1938, was extended with two 35-year-old steam turbine sets in 1942, and further extended with one 30-year-old steam engine unit. Previous history of these units included a number of changes when they were replaced with larger equipment. Fuel consumption at this particular plant went as high as 7.7 pounds of coal per kilowatt-hour, and it is loaded to 115 per cent of its rating even at present.

When importation of foreign-made generating equipment was nearly impossible, Chinese manufacturers tried to produce it locally. Many of these manufacturers worked in conjunction with the electricity department of the National Resources Commission to produce as much generating equipment as possible. From 1943 to 1945 enough boiler plants, steam turbine generators, gas engine generators, water wheel generators, and allied electric apparatus was manufactured locally to install more than 7,000 kw. To decrease fuel consumption, and because water wheels are simpler to manufacture than other types of prime movers, the National Resources Commission exerted every effort in developing water power. Southwest and northwest China are rich in hydroelectric sources, and soon after outbreak of the war, the Commission started to investigate different rivers, and collected various data and made preliminary designs. Because of the shortage of materials and financial and technical support during wartime, only a few small projects were developed.

Of all the utilities in free China, the Chungking Power Company was the largest with an installed capacity of 11,000 kw. After continuous usage and deferred maintenance, available capacity has been reduced to about 8,000 kw. The wartime capital had a population of over 1,200,000, and had a great number of factories. The power shortage was such that one third of the city was, in turn, out of supply every day. Even with restrictions, the machines were loaded beyond available capacity with consequent voltage dip varying from 40 to 20 per cent, which was looked upon as normal. This condition was not special to Chungking, and even now 1½ years

The living standard in China has declined to a very low point and reconstruction is needed urgently. Revitalization dependent on electrification on a broad national scale hinges on a contemplated generating capacity to be constructed of more than 1,100,000 kw. Although simultaneous reconstruction and expansion is a slow and difficult process, careful planning and co-ordination of the entire national project will speed its completion.

after victory, many cities face the same situation. Shortage of materials, and financial and technical support were not helped by the destruction of many newly-built plants by the Japanese.

Although the 50,000-kw total generating capacity distributed over the vast area of free China in 1945 was small, it was more than twice the corresponding capacity before the war. Progress during wartime was slow, but small-scale industrial development has started in the interior.

Captive plants which moved with evacuated factories helped to solve the power shortage problem in free China. The factories, which were not bothered with maintenance of service, shipped their power plants in better order than the utilities. According to a general survey made by the authors at the end of 1944, a total of 32,000 kw of captive plant capacity was put up in free China, more than the prewar total of about 4,700 kw.

PRESENT CONDITION OF THE INDUSTRY

The Japanese during their long stay in Taiwan (Formosa) and in the northeastern provinces (Manchuria) carried out considerable development of the power industries of these areas. Taiwan was provided with 320,000-kw capacity and the northeastern provinces had about 2,000,000 kw. The Japanese did not do much new construction work in the main part of China. War destruction, damage through long periods of maloperation, and deferred maintenance have reduced total available capacity to about one half its previous figure. The National Resources Commission and other power companies have exerted great efforts to repair damaged equipment. Shortage of new equipment from abroad and shortage of a foreign currency reserve in China has slowed progress considerably. The United Nations Relief and Rehabilitation Administration and the Chinese National Relief and Rehabilitation Administration consented to give some help, but complicated procedures and difficulties of delivery situation delayed arrival of UNRRA power plants to nearly 20 months after *V-J* Day. Up to the end of 1946, power plant equipment supplied by UNRRA to China consisted of ten 500-kw package power plants, eight 150-kw Diesel-electric sets, 205.8 tons of copper wires, and some miscellaneous electric equipment.

TAIWAN

Taiwan was under Japanese occupation for more than 50 years, and the colonial policy of Japan aimed at the exploitation of the island. During the war it was a production base and consequently the Japanese did considerable work there, especially in developing water power resources. Of the 34 power stations supplying the two systems on the island, 26 are hydroelectric plants with 270,000 of the 320,000-kw installed capacity. Besides supplying power to the aluminum, calcium carbide, caustic soda, mining, and other industries, the distribution systems extends to remote rural places. Generation, transmission, and distribution of electric power for Taiwan is under the management of the Taiwan Power Company, reorganized after *V-J* Day and jointly owned by private interests, the provincial government, and the National Resources Commission. When Taiwan was transferred to the Chinese Government after the war only 40,000 kw capacity could be utilized because of damage from war and a severe typhoon. When the Chinese took over the island, immediate steps were taken to restore power supply. American consulting engineers of the J. G. White Engineering Corporation, New York, N. Y., were invited to make a survey and a plan for its rehabilitation. Lack of spare parts and shortage of of raw materials has prevented work from being carried out as thoroughly as was desired. Nevertheless, the total available capacity has been increased to 130,000 kw with a peak load of about 75,000 kw. Most of the industries, especially the aluminum and fertilizer plants, which are large consumers, are still not in operation, and Taiwan is the only place in China where power supply is adequate. The number of consumers, including large and small ones, is about 402,000, which indicates that roughly one out of two households in Taiwan is wired for electricity.

NORTHEASTERN PROVINCES

The northeastern provinces are the richest region of China so far as natural resources are concerned. When the Japanese occupied the area, which then had about 200,000 kw of generating equipment, they began to exploit it and develop it into a war production area. Starting in 1937 when the Sino–Japanese war broke out, the Japanese carried out their first 5-year industrial plan which was completed in 1941. Electric power capacity increased in the five years from 412,400 kw to 1,108,300 kw. The second 5-year plan was started in 1942 with the goal to attain 2,600,000 kw at its completion. At the time of *V-J* Day there were already about 1,770,000 kw installed. With about 700,000-kw surplus capacity the situation in the northeast provinces would have been very promising if the Soviet Army during its short stay in the latter part of 1945 had not dismantled and removed almost all the new and efficient equipment for a total of about 1,400,000 kw, including about 400,000 kw under construction. At present only 414,150-kw capacity is operated by the Northeastern Power Administration, a subsidiary organization of the National Resources Commission. Only 245,000 kw is actually in running condition.

The Northeastern Power Administration has made considerable effort during the last several months in promoting power production from whatever equipment has been on hand, and is maintaining transmission systems which constantly are damaged by the Communists or bandits. The great hydroelectric project at Fengman with its two 70,000-kw water wheel sets is the main

source of supply. Civil engineering work on the dam is not complete, and because of rushing of work under the military command when the Japanese engineers were forced to discard precautions and engineering standards, it is in a very precarious condition. A group of engineers including J. S. Cotton (M '45), formerly of the United States Federal Power Commission and now chief engineer of the National Hydroelectric Engineering Bureau of the National Resources Commission, have been sent to Fengman to make a detailed study. According to Mr. Cotton, keyways were not provided and the safety factor of the dam is only one when flood water reaches the top of the spillway, which might cause the dam to topple under such a situation. To add to the gravity of the situation, water behind the dam can be drawn off only through the water wheels, and the reservoir level was not sufficiently lowered last winter which put the 6,000,000 farm population below the dam in danger because the 10-year cycle of maximum flood is already one year overdue.

FUTURE PROSPECTS AND PLANNING

The National Resources Commission, together with other related organizations, drafted a postwar electrical reconstruction plan as early as 1943–44 which called for an addition of 1,310,000 kw of steam power and 528,000 kw of hydroelectric power for a total of about 2,500,000 kw for China within the first five years following the war. The plan was made in Chungking during the war, but unexpected internal conflict after the Japanese surrendered, together with general economic deterioration and many other factors, changed the conditions so much that the original plan no longer fits the requirements. However, the basic principles of the plan still can be followed. The task of the future is twofold. For the first part of the program, it is pertinent to seek relief from the situation by whatever means available even if they do not conform with engineering standards and economic principles. For the inspection and repair of generating, transmission, distribution, and service equipment of all power plants and the procurement of spare parts and raw materials, about $10,000,000 (United States currency) plus the necessary Chinese national currency to defray all local expenses, is required.

The second stage of the task, construction of electric networks, is the heavier one. With the general economic condition of China rather poor, only those regions where the purchasing power of the people is relatively high and the natural resources are rich are to be developed first. Any investment in such areas soon will have more immediate return. The following networks are planned tentatively:

1. The northeast region covering the whole area of existing main networks.
2. The Taiwan district covering the whole area of the existing network on the island.
3. The North Hopei district including Peiping and Tientsin.
4. Shantung district having important cotton textile, coal, and aluminum cities.
5. The Kiangnan district covering the rich area of the lower Yangtze delta.
6. The central Kwangtung district including Canton.
7. The south Hopei district including Hankow and the Tayoh iron mine.
8. The central Hunan district.
9. The eastern Szechuen district including Chungking and the Chikiang iron mine.
10. The central Szechuen district with salt and sugar industries.
11. The western Szechuen district with salt and wood industries.
12. The Kunming district with iron and aluminum industries.

The afore-mentioned districts may be divided into two groups. Districts 1 through 6 have been industrialized already to some extent. The other six districts are either just on the threshold of industrialization, or only show the possibility of being industrialized. Whether they will be developed fully depends on such factors as transportation facilities, power supply, and raw materials. When all other conditions are favorable, each district will be developed gradually if cheap and adequate electric power is available.

Whether steam plants or hydroelectric plants should have preference depends upon conditions. Steam plants are advantageous because:

1. They require less time to construct.
2. Less investment per kilowatt capacity is required.
3. Steam plants in the Japanese reparation list can be utilized.
4. Steam plants involve fewer problems with local government.
5. Firm capacity per kilowatt capacity involved is greater.
6. Production cost is comparable if the plant is located at a mine mouth.

Hydroelectric projects are advantageous because:

1. Usually the generation cost is lower.
2. Management is simpler.
3. Fuel is saved which might be used for other purposes.
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after victory, many cities face the same situation. Shortage of materials, and financial and technical support were not helped by the destruction of many newly-built plants by the Japanese.

Although the 50,000-kw total generating capacity distributed over the vast area of free China in 1945 was small, it was more than twice the corresponding capacity before the war. Progress during wartime was slow, but small-scale industrial development has started in the interior.

Captive plants which moved with evacuated factories helped to solve the power shortage problem in free China. The factories, which were not bothered with maintenance of service, shipped their power plants in better order than the utilities. According to a general survey made by the authors at the end of 1944, a total of 32,000 kw of captive plant capacity was put up in free China, more than the prewar total of about 4,700 kw.

PRESENT CONDITION OF THE INDUSTRY

The Japanese during their long stay in Taiwan (Formosa) and in the northeastern provinces (Manchuria) carried out considerable development of the power industries of these areas. Taiwan was provided with 320,000-kw capacity and the northeastern provinces had about 2,000,000 kw. The Japanese did not do much new construction work in the main part of China. War destruction, damage through long periods of maloperation, and deferred maintenance have reduced total available capacity to about one half its previous figure. The National Resources Commission and other power companies have exerted great efforts to repair damaged equipment. Shortage of new equipment from abroad and shortage of a foreign currency reserve in China has slowed progress considerably. The United Nations Relief and Rehabilitation Administration and the Chinese National Relief and Rehabilitation Administration consented to give some help, but complicated procedures and difficulties of delivery situation delayed arrival of UNRRA power plants to nearly 20 months after *V-J* Day. Up to the end of 1946, power plant equipment supplied by UNRRA to China consisted of ten 500-kw package power plants, eight 150-kw Diesel-electric sets, 205.8 tons of copper wires, and some miscellaneous electric equipment.

TAIWAN

Taiwan was under Japanese occupation for more than 50 years, and the colonial policy of Japan aimed at the exploitation of the island. During the war it was a production base and consequently the Japanese did considerable work there, especially in developing water power resources. Of the 34 power stations supplying the two systems on the island, 26 are hydroelectric plants with 270,000 of the 320,000-kw installed capacity. Besides supplying power to the aluminum, calcium carbide, caustic soda, mining, and other industries, the distribution systems extends to remote rural places. Generation, transmission, and distribution of electric power for Taiwan is under the management of the Taiwan Power Company, reorganized after *V-J* Day and jointly owned by private interests, the provincial government, and the National Resources Commission. When Taiwan was transferred to the Chinese Government after the war only 40,000 kw capacity could be utilized because of damage from war and a severe typhoon. When the Chinese took over the island, immediate steps were taken to restore power supply. American consulting engineers of the J. G. White Engineering Corporation, New York, N. Y., were invited to make a survey and a plan for its rehabilitation. Lack of spare parts and shortage of of raw materials has prevented work from being carried out as thoroughly as was desired. Nevertheless, the total available capacity has been increased to 130,000 kw with a peak load of about 75,000 kw. Most of the industries, especially the aluminum and fertilizer plants, which are large consumers, are still not in operation, and Taiwan is the only place in China where power supply is adequate. The number of consumers, including large and small ones, is about 402,000, which indicates that roughly one out of two households in Taiwan is wired for electricity.

NORTHEASTERN PROVINCES

The northeastern provinces are the richest region of China so far as natural resources are concerned. When the Japanese occupied the area, which then had about 200,000 kw of generating equipment, they began to exploit it and develop it into a war production area. Starting in 1937 when the Sino–Japanese war broke out, the Japanese carried out their first 5-year industrial plan which was completed in 1941. Electric power capacity increased in the five years from 412,400 kw to 1,108,300 kw. The second 5-year plan was started in 1942 with the goal to attain 2,600,000 kw at its completion. At the time of *V-J* Day there were already about 1,770,000 kw installed. With about 700,000-kw surplus capacity the situation in the northeast provinces would have been very promising if the Soviet Army during its short stay in the latter part of 1945 had not dismantled and removed almost all the new and efficient equipment for a total of about 1,400,000 kw, including about 400,000 kw under construction. At present only 414,150-kw capacity is operated by the Northeastern Power Administration, a subsidiary organization of the National Resources Commission. Only 245,000 kw is actually in running condition.

The Northeastern Power Administration has made considerable effort during the last several months in promoting power production from whatever equipment has been on hand, and is maintaining transmission systems which constantly are damaged by the Communists or bandits. The great hydroelectric project at Fengman with its two 70,000-kw water wheel sets is the main

source of supply. Civil engineering work on the dam is not complete, and because of rushing of work under the military command when the Japanese engineers were forced to discard precautions and engineering standards, it is in a very precarious condition. A group of engineers including J. S. Cotton (M '45), formerly of the United States Federal Power Commission and now chief engineer of the National Hydroelectric Engineering Bureau of the National Resources Commission, have been sent to Fengman to make a detailed study. According to Mr. Cotton, keyways were not provided and the safety factor of the dam is only one when flood water reaches the top of the spillway, which might cause the dam to topple under such a situation. To add to the gravity of the situation, water behind the dam can be drawn off only through the water wheels, and the reservoir level was not sufficiently lowered last winter which put the 6,000,000 farm population below the dam in danger because the 10-year cycle of maximum flood is already one year overdue.

FUTURE PROSPECTS AND PLANNING

The National Resources Commission, together with other related organizations, drafted a postwar electrical reconstruction plan as early as 1943–44 which called for an addition of 1,310,000 kw of steam power and 528,000 kw of hydroelectric power for a total of about 2,500,000 kw for China within the first five years following the war. The plan was made in Chungking during the war, but unexpected internal conflict after the Japanese surrendered, together with general economic deterioration and many other factors, changed the conditions so much that the original plan no longer fits the requirements. However, the basic principles of the plan still can be followed. The task of the future is twofold. For the first part of the program, it is pertinent to seek relief from the situation by whatever means available even if they do not conform with engineering standards and economic principles. For the inspection and repair of generating, transmission, distribution, and service equipment of all power plants and the procurement of spare parts and raw materials, about $10,000,000 (United States currency) plus the necessary Chinese national currency to defray all local expenses, is required.

The second stage of the task, construction of electric networks, is the heavier one. With the general economic condition of China rather poor, only those regions where the purchasing power of the people is relatively high and the natural resources are rich are to be developed first. Any investment in such areas soon will have more immediate return. The following networks are planned tentatively:

1. The northeast region covering the whole area of existing main networks.
2. The Taiwan district covering the whole area of the existing network on the island.
3. The North Hopei district including Peiping and Tientsin.
4. Shantung district having important cotton textile, coal, and aluminum cities.
5. The Kiangnan district covering the rich area of the lower Yangtze delta.
6. The central Kwangtung district including Canton.
7. The south Hopei district including Hankow and the Tayoh iron mine.
8. The central Hunan district.
9. The eastern Szechuen district including Chungking and the Chikiang iron mine.
10. The central Szechuen district with salt and sugar industries.
11. The western Szechuen district with salt and wood industries.
12. The Kunming district with iron and aluminum industries.

The afore-mentioned districts may be divided into two groups. Districts 1 through 6 have been industrialized already to some extent. The other six districts are either just on the threshold of industrialization, or only show the possibility of being industrialized. Whether they will be developed fully depends on such factors as transportation facilities, power supply, and raw materials. When all other conditions are favorable, each district will be developed gradually if cheap and adequate electric power is available.

Whether steam plants or hydroelectric plants should have preference depends upon conditions. Steam plants are advantageous because:

1. They require less time to construct.
2. Less investment per kilowatt capacity is required.
3. Steam plants in the Japanese reparation list can be utilized.
4. Steam plants involve fewer problems with local government.
5. Firm capacity per kilowatt capacity involved is greater.
6. Production cost is comparable if the plant is located at a mine mouth.

Hydroelectric projects are advantageous because:

1. Usually the generation cost is lower.
2. Management is simpler.
3. Fuel is saved which might be used for other purposes.
4. Coal mine strikes and transportation interruptions do not affect power production.
5. Irrigation, flood control, soil preservation, and navigation facilities are included in a hydroelectric project.

This program calls for an addition of more than 1,100,000 kw capacity within three to five years, to be built mostly with equipment from Japanese reparation. Nearly all extensions of hydroelectric power facilities scheduled for completion are unfinished projects laid by the Japanese. In this way the least capital will be required to obtain the greatest results. However, according to the rough estimate of the authors, at least $75,000,000 (United States currency) is required to cover purchases from abroad for generation, transmission, and distribution equipments, a sum seemingly out of reach for the present China.

Field Problems in Balancing Rotating Electric Machinery

R. B. BARTON

Although vibration problems are covered in detail by many textbooks, practical examples of field work serve to point out methods of approach for correcting unbalance.

MANY VIBRATION problems stem from other than dissymmetry of rotating parts. Mechanical disturbances, thermal disturbances, instability, and straightforward balance problems may cause serious trouble. The fundamental principles governing unbalance are not new and may be found in many textbooks.[1,2]

The whirl which occurs as a shaft runs is not altered materially by the flexibility which exists in all bearing supports. The shape which the shaft takes, however, does change as more motion is introduced at the bearing supports.[3] The frequency at which the resonance occurs is lowered by this flexibility and a second frequency usually appears, as vertical and horizontal flexibilities are generally different.

FIELD METHODS

In the practical approach to the field solution of a balance problem, many things must be considered:

1. The nature of the vibration which exists.
2. The value of reducing the vibration.
3. The physical counterparts of the system to be attacked, and the expected configuration of the shaft.
4. The system to be followed in solving the problem.

A specific limit of vibration amplitude for all rotating machinery cannot be determined easily. Each type of rotating apparatus must be considered individually and satisfactory limits set. Limits of acceptable vibration are based on the designer's judgment. His judgment, in turn, is based on the effect a given vibration is having on the life of the equipment. Where excessive wear takes place or amplitudes are stressing parts, there is little question as to the desirability for correction. When the vibration amplitude is already low, the time and effort required to reduce vibration from an already low value to one approaching perfection is definitely questionable. How, then, does one decide where to stop? Most manufacturers set limits, which can be considered reasonable for long life of parts. The exception to this principle occurs when the observed vibration is a result of disturbances other than dissymmetry of rotating parts.

The system to be approached should be scrutinized carefully for relative size of component parts, method of support, number of major parts, and proximity to resonance. For example, the simple 2-bearing arrangement may be

1. A stiff design (designed with the calculated critical point above running speed).
2. A flexible shaft design (designed to pass through one or more critical points).

The stiff shaft design usually will run below resonance but it may run just above resonance. In this instance, the shaft tends to run in a 1 loop form and will respond to static-type correction. (Figure 1*A*.) A shaft running well below resonance may be corrected by the simple expedient of a pair of static weights. The resultant static unbalance M is corrected by adding $1/2\ M$ at each end of the rotor body and the rotor will be in balance at the operating speed.

The flexible shaft design always runs above the first resonance and may approach or run above the second resonance. This design runs through the 1-loop form of Figure 1*B* and into the 2-loop form of Figure 1*C*. The approach to this problem is made in two parts, one statically and one dynamically.

A shaft operating near the first critical point tends to bend from the centrifugal forces of unbalance. This bending introduces additional unbalance which may be more important than the initial unbalance. A uniform shaft with unbalance M of Figure 1*B*, corrected at a distance from the bearing of one-sixth of the shaft length, will require a correction of M at each end in the limiting case of negligible damping. Actual flexible rotors are not uniform shafts. Their design is such that bending along the length is reduced to a small value. Some instances of bending do exist, however, and this effect must be considered in balancing.

The shaft operating near the second critical point is corrected by two equal diametrically opposed weights, one at each end of the rotor. The dynamic unbalance must be large to create a disturbance at the first critical point. The degree of importance of the dynamic unbalance to the static unbalance is related directly to the proximity of the second critical point to running speed.

Essential substance of a conference paper, "Field Problems in Balancing Rotating Electric Machinery," presented at the AIEE Pacific general meeting, San Diego, Calif., August 26–29, 1947.

R. B. Barton is in the engineering division of the General Electric Company, Los Angeles, Calif.

Three bearing sets complicate the problem as one more rotor has been added and the relation of the resonances of the individual rotors determines the complexity of the problem.

Four, five, and six bearing sets are not inherently more difficult than two bearing sets, except where insufficient independence exists between rotors.

The system followed in solving the problem once the fact that a balance problem exists is determined in general on the following:

1. Speed of the unit.
2. The speed and accuracy with which data may be obtained.
3. The known interference from forces other than unbalance.
4. The equipment available for obtaining data.
5. The familiarity of the operator with his equipment.

The individual conducting balance operations will choose the most expedient system after surveying the case.

Early in the history of balancing operations was, obviously, the hit-and-miss system later co-ordinated into the quartering method. The quartering method needs little explanation. It is a way to determine the amount and location of corrective weight by placing the trial correction at each of four 90-degree locations and adjusting the amount of weight at the best location. With a rotor having large shaft amplitudes and a known resonance, placing a mark on the shaft with a pencil or scribe will assist the operator in placing his first weight properly and thus reduce the number of runs necessary for determining the proper location of corrective weight. It is possible to refine the quartering method further by using a 2-trial run method known as the 3-vector method. In this instance, Figure 2, one run is made with no trial weight, the second made with a weight at an arbitrary location, and the third run with the weight moved 180 degrees. From the three amplitudes thus obtained, a vector diagram may be constructed to give the required location and amount of corrective weight needed.

The construction is ambiguous and may require a fourth run to determine the correct final location. If large amplitudes exist, a shaft mark may be used to remove the ambiguity from the vector construction.

In the last 15 years tools have been developed which help to remove the guesswork from balance operations.[4] It is well to point out here that the success of a given method is dependent on the familiarity of the operator with the method he is using and the wisdom which he uses in applying the information collected by the tools at his disposal.

Basically, all systems are founded on the premise that the vibratory system under consideration is linear; that is, that vibration is proportional to unbalance. In actual practice, this is not strictly true. Therefore, the judgment born of experience and the familiarity of the operator with the vibratory system and with his tools becomes a very important factor in the successful termination of a vibration problem.

PROBLEM SOLUTIONS

Some specific problems are of interest. Four types will be discussed.

Mechanical Disturbances. One interesting example occurred in 1946 when a horizontal synchronous condenser running at 600 rpm vibrated. The condenser was composed of two rotors, each with its own bearings. The two rotors were coupled together. When operated, they developed a 1-per-revolution pound not unlike synchronous vibration. Attempts to balance the sets quickly proved that some other disturbance existed when operator was unable to reduce the vibration at a given point below 1.3 mils without increasing the vibration at other points. The forces introduced by the misalignment at the coupling were too large to be compensated for by balance weights; therefore, the coupling check was made. The coupling was corrected and the set readily balanced to less than 0.9 mil at any point.

In 1941 a 20,000-kw turbine running at 1,800 rpm developed vibration. In this instance, a heavy rumble occurred starting at two-thirds speed, continuing to synchronous speed, and under load until approximately one-quarter load, where the noise stopped. Accompanying the rumble was a heavy vibration. A study of the vibration characteristics with instruments indicated a 3-per-revolution disturbance. The sound and the frequency of the heavy vibration, plus its relation to rotation speed and load, indicated that a loose wheel was causing the disturbance. Subsequent inspection of the rotor proved the analysis was correct. Any attempt to balance the vibration would have been useless.

A third case of vibration on a 3,600-rpm 2-bearing dynamometer illustrates still a different type of mechanical disturbance. In this instance, the dynamometer rotor was supported by ball bearings. The unbalance part of the problem was solved quickly by using the calculation system devised by E. L. Thearle.[4] The degree of refinement obtained, however, was not satisfactory, as the minimum vibration possible was $1^1/_4$ mils. Any further attempts to refine the rotor failed. At this point, a new set of precision ball bearings was installed and the vibration immediately was reduced to one-half mil.

In 1947, a case occurred on a vertical turbine generator running at 720 rpm. The set defied solution by ordinary balance methods. As the work progressed, the operator observed that the 50-ton rotor seemed to need a dynamic correction, yet when he pursued this type of correction, he could not reduce the vibration at all points simultaneously. The data obtained indicated that large dynamic corrections were needed, yet this only moved the vibration from one end of the machine to the other. Knowing that this type construction ordinarily should require only a static correction, he reasoned that the coupling must not be mated properly. A check of the coupling proved his suspicion when he found

the faces not parallel. The coupling was corrected and the balance then proceeded in an orderly fashion to a successful conclusion. Both the generator rotor and the turbine rotor required static weight correction to complete the work.

Thermal Disturbances. Thermal effects are inherently more difficult to determine than mechanical effects. Thermal effects may add, subtract, or bear some intermediate relation to the existing unbalance. The classic example of a thermal effect was analyzed in 1938.[5] Here the effect of liquid in a hollow shaft resulted in a phenomena called "spiral vibration." The effect was classified so because it rotated with respect to the existing unbalance and thereby first added to then subtracted from, the unbalance. The effect, however, increased in magnitude with time and eventually became excessive. Other cases of this type have occurred, notably one in

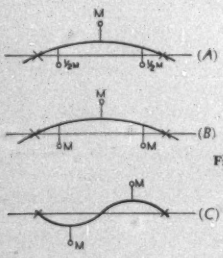

Figure 1. Vibrating forms for a simple 2-bearing shaft

A—One loop, stiff rotor
B—One loop, flexible rotor
C—Two loops, flexible rotor

which a rotor with a small amount of liquid in a sealed bore vibrated excessively when the operating temperature boiled the liquid at the high temperature end and condensed it at the low temperature end. In this instance, the rotor actually was bent from the temperature difference caused by the action of the liquid and the eccentricity of the bore. A similar case occurred where oil leakage into the rotor bore built up slowly over a period of years until enough oil accumulated to affect the heat transfer in the shaft. In this instance, the distortion effect was a straight line and, therefore, was a special case of the general theory of spiral vibrations.

Thermal effects are also present in generator rotors. The effect of short-circuited turns will cause magnetic unbalance. This effect also can alter the temperature distribution of the rotor and conceivably can cause a slight bow in the rotor, thus introducing an unbalance to be reckoned with. Fortunately, these cases are not severe and usually can be handled by a compromise balance.

In the past, instances have occurred in which steam leakage along the shaft of an assembled rotor resulted in a heat bow which required balance correction. Two characteristics were present in cases of this type.

1. The vibration of the unit would change with the application of load. This change could be followed with the data obtained through the use of instrumentation.

2. If the load was removed quickly, the vibration would remain unchanged.

Later, as uniform temperatures are reached, the vibration would change to values originally observed at partial loads. When the leakage progressed to a point where balancing no longer could deal with the problem adequately, the keyway was sealed and the problem solved. Present-day practice includes diametrically opposed sealed keyways which have eliminated the problem.

The one thermal problem most likely to trap the unsuspecting is the one involving stationary parts rubbing rotating parts. Here it is possible through little suspected deflectors and packing rings to begin unwarranted bal-

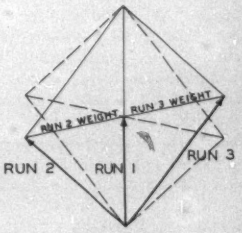

Figure 2. Vector diagram of the 3-vector method of solving a balance problem

ance operations. One vital factor in the mechanics of solving vibration problems is that the system respond in a consistent manner. One disturbing effect of rubbing is that the effect is not consistent. To attempt to balance a piece of apparatus that is rubbing is like trying to catch the brass ring on a merry-go-round with your eyes closed. There is an established fact that rotors running below the first major resonance will move into a rub, whereas a rotor running above the first major resonance will move away from a rub.

There is another type of thermal case in which the heat transfer from a long rotor was not uniform. Large turbine generators rotors are cooled with air passed through ventilating slots and discharging radially through holes into the air gap. One instance occurred where unequal distribution of air flow caused one side of the rotor to become hotter than the other. This condition resulted in a slight bow in the rotor. The extent of the bow and, consequently, the amount of unbalance was related to the field current and the ventilating air temperature. The temperature effect made it impossible to obtain a consistent balance for all values of field current. A redistribution of air flow from the rotor resulted in much improved operations.

Instability. One phenomenon that is likely to appear in high-speed rotating machinery is that of self-excited vibrations. Transmission lines are susceptible to self-excited vibration when conditions of wind and sleet exist.[6] Other authors[1,7,8] have treated the oil film whirl observed in rotating machinery. Generally, the action of "oil film whirl," also known as "oil whip," takes place in rotating machinery which operates at a speed of about twice the first major or static resonance of the system. The action is characterized by the fact that the frequency at which the action starts can be altered by the temperature of the oil supplied to the bearings. The frequency of the disturbance is very close to the frequency of the first major resonance, and it tends to remain at this frequency even though the operating speed is increased above the starting point of the disturbance. Some observations have been made in which a low-frequency disturbance has occurred at exactly half the operating speed with the frequency of the disturbance equal to the first major horizontal resonance. This half-speed disturbance would follow an increase in operating speed retaining the half-speed relation until the first major vertical resonance was reached. At this point, the low-frequency disturbances would cease to rise with the increase in operating speed and the behavior would agree with the familiar oil film whirl pattern.

The direct approach to a problem of this nature is first to determine that all ordinary mechanical and alignment requirements have been met. Once this has been determined, the substitution of a stable-type bearing sometimes will remove the exciting force and solve the problem. Among the stable-type bearings are the elliptical, the pressure, and the floating pad bearings.[9]

A 50,000-kw noncondensing steam turbine generator was known to develop a heavy vibration during periods of light load operation. An investigation was made and the evidence disclosed that, during light load periods, no effort was made to maintain a constant ambient temperature in the generator casing. Because there was no attempt to regulate generator temperatures, the generator casing was allowed to drop some 20 degrees centigrade. It was during these periods of cold generator operation that the vibration developed. The vibration frequency was found to be approximately 1,800 rpm and shaft vibrations increased to approximately ten mils. When generator temperatures were raised to normal, the vibration disappeared and shaft vibrations came back to previous values. Further investigation disclosed that in the interval between the initial installation and the first signs of distress, permanent changes had occurred in the foundation structure with the result that the turbine generator unit was no longer in proper alignment. The unit was restored to correct alignment and further tests conducted. With the unit in correct alignment, the effect of generator casing temperatures disappeared and no further disturbance occurred.

Other instances of oil film whirls have occurred where alignment and other mechanical features were in proper order. One particular example is a 1,200-kw turbine generator which operated at 3,000 rpm. This unit was subject to intermittent periods of low-frequency vibration. This low-frequency vibration was measured as 1,500 rpm, or half synchronous frequency. Careful checks of alignment and other mechanical features failed to remove the disturbance. Oil temperatures were altered with no appreciable effect. The bearing liners were altered to increase the unit loading and the unit went in service with no further evidence of low-frequency vibration.

Straightforward Balance Problems. The normal straightforward balance problem, as mentioned before, can be approached best by having, first, a knowledge of vibratory system. The proper method then may be selected and the balancing operation started. The following example is one approach to a normal problem. The unit, a medium size turbine generator, was operating with $1^1/_2$-mil vibration at the exciter end and 1-mil vibration in the middle and at the turbine end. The shaft vibrations were relatively large, being five mils in the middle. The set was a 4-bearing set and solidly coupled. An investigation of the unit throughout the entire speed range was made and it was determined that the first major resonance occurred at 2,000 rpm. The vibratory system of the rotor, stator, and foundation had a low amplifying ratio at resonance; therefore, the disturbance at the critical speed was low with a reasonable amount of residual unbalance. The problem was approached first by removing the major disturbance at the critical speed, and then refining the balance for the operating speed. A total of four runs was required to make the refinement. This instance represents the value of a knowledge of the equipment used and of the vibratory system being approached.

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High-Voltage Measurement

HAROLD L. LEVINTON
MEMBER AIEE

A SIMPLE METHOD for accurately measuring voltages present on high-voltage systems during both transient and steady-state conditions without modifying the conditions producing the voltage to be measured has been developed.

An electronic amplifier having high input resistance and negligible circuit loading provides adequate current to operate magnetic oscillograph galvanometers (or meters, relays) in proportion to the input voltage obtained from capacitance voltage dividers. Frequencies ranging from direct current to a hundred or more kilocycles are within the capability of the device, although the actual value, determined by the indicating or recording instrument which it actuates, may be limited to a few thousand cycles.

Any of a number of vacuum tube circuits may be used for producing relatively large currents which are proportional to the voltage obtained from the capacitance dividers. These circuits may represent amplifiers, bridges, oscillators, modulators, or cathode-followers.

This device utilizes the amplifier-bridge-type circuit shown in Figure 2. It is made from available radio parts and operates from 6-volt storage batteries (independent of station power sources). With no signal on the tube grid, the current through the galvanometer from one arm is balanced by the current in the other arm through adjustment of resistor R_4 until the galvanometer has zero deflection. The application of a voltage to the grid changes the tube resistance, unbalances the bridge, and deflects the galvanometer. Positive signal voltages decrease the tube internal resistance and negative signal voltages increase the tube internal resistance, thereby deflecting the galvanometer in opposite directions from its null or zero grid voltage position.

The tube also functions as an amplifier in that, while it produces an output current proportional to its grid signal voltage, it may be considered as amplifying the small signal current in its grid resistor R_1 circuit to a value sufficiently high to operate the galvanometer. The galvanometer deflection may be controlled by grid voltage adjustment through capacitance divider proportioning or by replacing R_1 with a grid circuit resistance voltage divider. Compensation of the resistance divider for wiring and tube capacitance is not required normally because of the comparatively low frequency response limit of magnetic galvanometers; however, if frequencies above 10,000 cycles per second are to be recorded, this correction should be considered. Where deflection amplitude is adjusted by capacitance divider proportions, frequency effects are not introduced by the wiring or tube capacitances if R_1 is noninductive.

An illustration of the results to be expected from amplifier-capacitance-voltage-divider combinations is given by Figure 3. The rectangular voltage trace

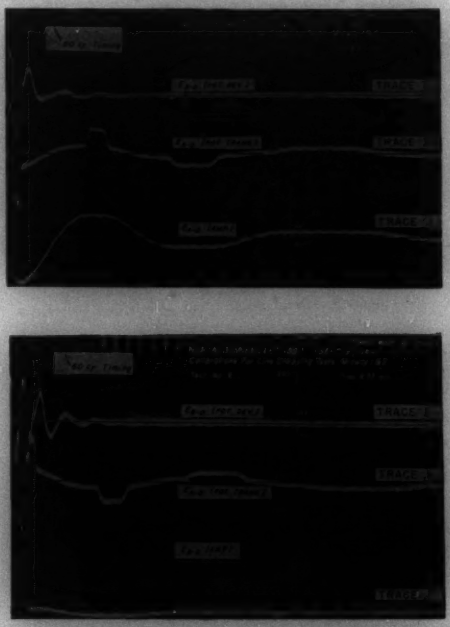

Figure 1. Line switching tests recorded by a capacitance potential device, a potential transformer, and the amplifier

A—Low-frequency oscillatory line voltage condition
B—Unidirectional line voltage condition showing trapped line charge. The true unidirectional voltage of the line following the interruption of charging current is modified by the presence of a potential transformer to a low-frequency oscillation voltage which is reproduced as a distorted wave. The capacitance potential device output voltage records are also incorrect

Essential substance of paper 47-203, "A Simple and Inexpensive Method for Accurately Measuring Steady-State and Transient High Voltages," presented at the AIEE Pacific general meeting, San Diego, Calif., August 26–29, 1947, and scheduled for publication in AIEE *TRANSACTIONS*, volume 66, 1947.

Harold L. Levinton is an electrical engineer with the Bonneville Power Administration, Portland, Oreg.

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A simple and inexpensive method for accurately measuring steady-state and transient high voltages without modification of the conditions producing the voltage to be measured long has been sought by utility engineers. An amplifier bridge used with a capacitance divider can be designed to fit the particular application.

obtained during the disconnecting switch operation is the result of the capacitance effect of the short section of bus and the oil circuit breaker bushing. As the switch first opens, the short bus and energized bus are at the same potential; the short bus having a d-c trapped charge corresponding to the crest voltage and the energized bus still varying sinusoidally. No current flows because, at the instant of contact separation, both bus sections have the same potential. A little later the energized-bus voltage changes because of its 60-cycle sinusoidal periodicity until the difference in potential between the busses is sufficient to arc over the switch gap or restrike. The voltage of the short bus then changes with extreme rapidity, because of its low value of capacitance, to the bus voltage during a very brief flow of current of high initial magnitude. When the short bus reaches the voltage of the energized bus (neglecting high-frequency oscillations which may be present) the current flow ceases and the short bus again is left with a d-c charge until the bus voltage departs sufficiently to again break over the switch gap when the process is repeated. As the disconnecting switch is being opened, the voltage necessary for its gap breakdown increases, as may be seen from the oscillogram of Figure 3, until the gap gets long enough to withstand the voltage difference between the busses or double-crest voltage.

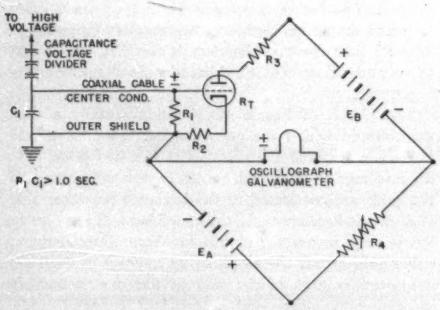


Figure 2. Oscillograph amplifier basic circuit

Amplifiers are especially convenient for measuring the voltage across circuit breakers during fault current or line-charging current interruption. In this service a capacitance voltage divider is connected to each side of the circuit breaker; these may be made with the circuit breaker bushing capacitances. Auxiliary capacitance values connected between the two tap points and ground should be adjusted so that both dividers will have the same tap voltage when the dividers are energized by the same high voltage. An amplifier connected between the tap points will respond to the difference between the two voltages to ground. Because of the large tap-to-ground auxiliary capacitance and the low tap-to-ground voltage (usually ranging between 25 and 60 volts depending on the installation), no trouble should result from the amplifier chassis not being grounded metallically.

Another interesting use for the amplifier is the measurement of neutral-to-ground transient voltages on ungrounded systems or on equipment like ungrounded Y static capacitors. An amplifier connected to a capacitance divider between the neutral point and ground will give quite satisfactory performance without affecting the neutral circuit conditions. For this condition the capacitance divider should have as small

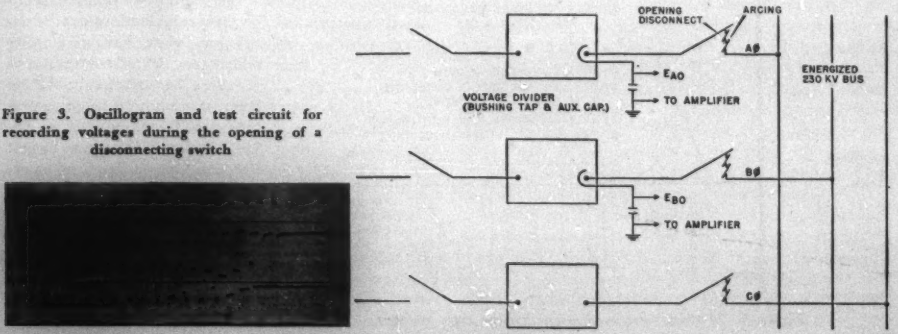


Figure 3. Oscillogram and test circuit for recording voltages during the opening of a disconnecting switch

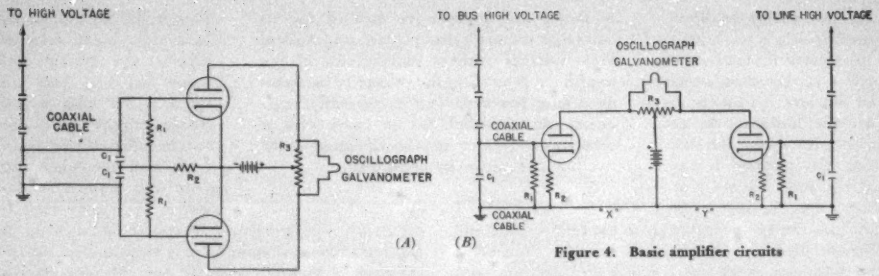


Figure 4. Basic amplifier circuits

an effective over-all capacitance value as possible; in no instance should this effective value approach the neutral-to-ground capacitance of the circuit being measured. If no physical neutral exists, three additional matched capacitors forming an ungrounded Y connection to the test circuit can be used to form the neutral.

In all the previous discussion it has been assumed that some form of meter indication of the steady-state 60-cycle voltage is available as an oscillogram calibration reference. Where no calibration reference voltage is available, either the voltage division ratio or capacitance value ratio of the voltage divider is necessary. The deflection of the oscillograph galvanometer for a known low voltage applied to the amplifier tube grid circuit then can be correlated with the voltage divider ratio to give a calibration corresponding to the high-voltage system.

Figure 4 shows two types of amplifiers which obviate the need of special balancing voltages. The static (zero signal) plate current is kept from the oscillograph galvanometer by balancing the plate current of one tube against the plate current of the other tube.

In Figure 4*A* the relative grid–cathode voltages of the two tubes are 180 degrees out of phase so the oscillograph galvanometer is subjected to a difference current whose magnitude is proportional to the voltage across the capacitors C_1. The series connection of these capacitors makes their value twice as large as in other forms of amplifiers without lowering the tap voltage. The *RC* time constant therefore is doubled, which may be very advantageous for unidirectional voltage measurement.

The circuit of Figure 4*B* is fundamentally a dual amplifier in which the galvanometer responds to the difference between the voltages to the two grids; the same voltage on both grids results in zero deflection. If the grids are connected to the bushings on either side of a circuit breaker tank, the amplifier will respond to the voltage across the circuit breaker. De-energizing either grid causes the amplifier to respond to the line-to-ground voltage of the side of the circuit breaker energizing the other grid. At points *X* and *Y* additional galvanometers may be connected in the same manner as in the amplifier of Figure 2. If this is done, one amplifier can operate three oscillograph galvanometers for recording the line-side voltage, the bus-side voltage, and the voltage across the circuit breaker.

Any number of similar circuits or their combinations can be developed, each having features which may be advantageous to the user. In most circuits of these types, care must be taken to provide a sufficient number of adjustable circuit elements so that not only can the zero signal tube currents be balanced out to give zero galvanometer deflection, but the same value of high voltage should give the same galvanometer deflection irrespective of the capacitance-divider-tube combination to which it may be applied.

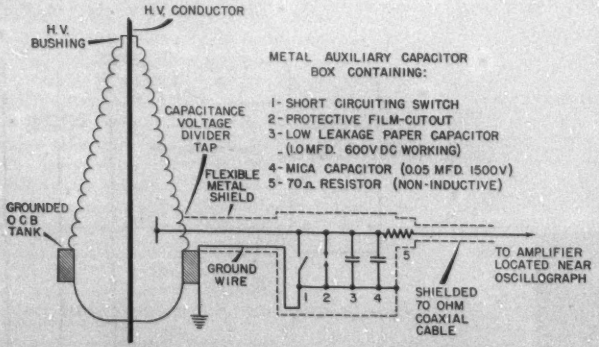

H.V. CONDUCTOR
H.V. BUSHING
METAL AUXILIARY CAPACITOR BOX CONTAINING:
1- SHORT CIRCUITING SWITCH
2- PROTECTIVE FILM-CUTOUT
3- LOW LEAKAGE PAPER CAPACITOR (1.0 MFD. 600V DC WORKING)
4- MICA CAPACITOR (0.05 MFD. 1500V)
5- 70Ω RESISTOR (NON-INDUCTIVE)
CAPACITANCE VOLTAGE DIVIDER TAP
FLEXIBLE METAL SHIELD
GROUNDED OCB TANK
GROUND WIRE
1 2 3 4 5
TO AMPLIFIER LOCATED NEAR OSCILLOGRAPH
SHIELDED 70 OHM COAXIAL CABLE

Figure 5. Method used to measure system high voltages

CAPACITANCE POTENTIAL DIVIDERS

Capacitance potential dividers were chosen for use with the amplifier because of their convenience. Without any special installation, they are usually available in 230-kv switchyards in the form of bushing taps, carrier coupling capacitors, or even insulator units; when not otherwise available, special capacitance divider installations easily are installed.

All of these installations result in higher voltage between ground and the lowest voltage point on the divider than can be used conveniently, the voltage generally ranging from 3,000 to 30,000 volts. Therefore, it is necessary to place supplemental or auxiliary capacitance between ground and the tap point to lower the tap voltage to ground to a value ranging between a few volts and a few hundred volts, depending on the nature and purpose of the installation. Auxiliary capacitance values range from 10 or 20 micromicrofarads when low tap-to-ground voltage is desired to 0.1 micromicrofarad for higher values of tap-to-ground voltage.

Figure 5 is a sketch showing the method usually employed to connect the amplifier to a capacitance voltage divider. The auxiliary capacitors and other accessories used are housed in a metal weather protecting box. Various bushing tap fittings may be connected to the auxiliary capacitance boxes by means of conductors shielded from electrostatic fields by flexible metal tubing. Heavy ground wires are brazed to the two ends of the flexible tubing to overcome possible inductive effects from the spiraled construction of the flexible tubing.

Coaxial cable circuits between the auxiliary capacitor boxes and amplifiers are to be preferred as they minimize the possibility of electrostatic or electromagnetic effects. Although Figure 5 employs a bushing tap to form the capacitance voltage divider, any capacitors that have adequate insulation and suitable characteristics may be used. These include carrier-coupling capacitors, static-capacitor units, and insulators. Where capacitor components have low values of capacitance and comparatively large area, such as insulator units, considerable care must be exercised in shielding the divider from other electrostatic fields in the vicinity.

Photography at Five Million Frames Per Second

A motion picture camera that can take more than five million pictures a second has been described before the Optical Society of America by Doctor B. O'Brien, director of the Rochester Institute of Optics at the University of Rochester, N. Y. Taking motion pictures at such speeds by conventional means is very difficult because of the mechanical and optical problems involved.

These difficulties are avoided if the image of the rectangular picture is broken up into a series of very narrow strips which then are reassembled, end to end, into one long narrow strip. In the new camera this image dissection is accomplished by a stationary optical system of somewhat unusual properties, and the single long and narrow strip made up of the dissected elements of the original picture is imaged on the negative film as a line so narrow that it is less than the resolving power of the film itself. The film is driven past this line image, and in a direction perpendicular to the line, at the comparatively high speed of 400 feet per second. This is accomplished by containing the film on the inside of a shallow rotating drum where it is held in position by centrifugal force 16,000 times gravity.

The narrow strip image is drawn out by the moving film into a streak, and the variations in photographic negative density at any place across this streak contain all the elements of a complete rectangular picture for the particular instant of time represented by the position selected along the streak. The negative film need move by only the width of the narrow slit image to produce a complete new frame of the original rectangular event or picture. As the camera is shutterless the motion of the film produces a blurring of the image, but this blurring is limited to the width of the slit which is no more than the resolving power of the negative film itself.

After processing, the negative must be reconstructed into the original rectangular picture by projection back through an optical system similar to that which formed it. This is done by an automatic projection printer which produces an ordinary 16-millimeter motion picture print which can be run through an ordinary projector. In the present camera the negative is enlarged tenfold in printing back to a 16-millimeter motion picture frame. Thus the film grain imposes a serious limitation on picture quality although the resolving power secured is adequate for the study of many subjects. The nominal rating of the present camera is five million frames per second, but the behavior is still satisfactory at higher speeds. The exposure time is approximately one seven-millionth of a second, but because of the peculiar arrangements of optical system and film the interval between frames can be less than the exposure time while still preserving the continuity of the picture.

The camera is being applied to the study of certain electric discharges, and is expected to be especially useful in this field. It is also well adapted to investigation of high explosive shaped charge phenomena and certain shock front effects. The camera is expected to have a considerable range of applications.

Series Capacitors on Distribution Circuits

R. E. MARBURY
FELLOW AIEE

J. B. OWENS
ASSOCIATE AIEE

Application of series capacitors to distribution circuits involves several factors that must be considered carefully if the installation is to operate properly. A careful analysis of the conditions under which the series capacitor is to operate must be made; maximum and momentary current and by-pass provisions for excess currents must be considered.

A CAPACITOR connected in series with an electric circuit effectively cancels inductive reactance in the circuit and thus improves voltage regulation. It is particularly useful on circuits where lamp flicker is encountered because of rapid and repetitive load fluctuations such as are caused by spot welding machines. Voltage regulators are not sufficiently rapid to follow these sudden fluctuations. The voltage dip cannot be prevented by regulators as the dip itself is used to initiate the correction. A series capacitor serves as an automatic voltage regulator with practically instantaneous response and may be effective in reducing flicker caused by any type of fluctuating load.

Even when lamp flicker is not present, a series capacitor can be used instead of a transformer-type regulator to improve voltage regulation on a circuit having a high reactive voltage drop. In general, the regulator is less expensive; however, the capacitor may be justified on long circuits, 2,400 volts or above, that supply small amounts of power.

A series capacitor improves voltage regulation by compensating for the voltage drop caused by reactance in the circuit; therefore, the improvement that can be obtained depends upon what portion of the voltage drop is caused by circuit reactance. It will give a worthwhile improvement in voltage when the following conditions exist:

1. The circuit reactance is equal to or greater than the circuit resistance.
2. The load has a low power factor.

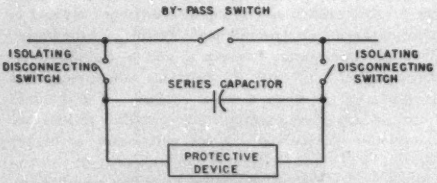


Figure 1. Disconnecting switch arrangement for each phase of series capacitor installation

Series capacitors should be considered only when a power factor correction of the load with shunt capacitors does not give the desired results. When a low power factor load causes an excessive steady state voltage drop the condition should be corrected with a shunt capacitor rather than a series capacitor for economic reasons.

PRINCIPLE OF OPERATION

The voltage drop on one phase of an electric circuit having a lagging power factor (with or without series capacitors) can be computed approximately as follows:

$$V = iR \cos\theta + i(X_L - X_C) \sin\theta \qquad (1)$$

where

R = total circuit resistance
X_L = total circuit reactance
X_C = series capacitance, if used
i = load current
θ = power factor angle of the load

From this expression it is seen that with high power factor loads the resistance drop in the circuit is a large portion of the total drop and the reactance drop portion of the equation is of little consequence. In such instances, a series capacitor is usually not effective. If the power factor of the load is low, the voltage drop caused by the reactance will become appreciable, particularly if X_L is large, and a series capacitor can be used to advantage because it has the effect of directly compensating for the inductive reactance X_L. If the reactance of the capacitor is made equal to the reactance of the circuit, there will be no steady-state reactive drop and the circuit will behave essentially as if there were only resistance present.

If the load power factor is low and nearly constant for all values of load current, the reactance of the capacitor can be made greater than the inductive reactance of the circuit to compensate in part or in whole for the resistance drop in the circuit. If the load power factor varies as it usually does on distribution circuits, the regulation can be improved in some cases by overcompensation. Such an application should be made only after a careful study of load distribution and variation.

A capacitor connected in series with a distribution

R. E. Marbury is manager of the capacitor section and J. B. Owens is capacitor engineer, Westinghouse Electric Corporation, East Pittsburgh, Pa.

circuit causes an increase in the line voltage on the load side of the capacitor. The magnitude of this increase is approximately equal to $iX_c \sin \theta$. On a circuit having a single load at the end of the line, the voltage at the load will be the same for any location of the capacitor. When loads are distributed along the line, however, it is desirable to locate the capacitor so that the voltage distribution along the line is most nearly uniform. In general, this is accomplished when the capacitor is placed so that the voltage drop between the source and the capacitor is equal to one-half the rise produced. Care should be exercised to be sure the rise in voltage does not place overvoltage on transformers located immediately after the series capacitor.

SERIES CAPACITOR EQUIPMENT

Protection During Line Fault. In most circuits in which series capacitors are applied, the currents and corresponding capacitor voltages during fault conditions are many times the maximum working value. As capacitor units can withstand only 200 per cent of their rated working voltage for brief periods without damage to the dielectric, it is necessary to use capacitors with continuous current ratings equal to 50 per cent of the maximum current that may flow during a fault, or to use a voltage limiting device. For a given reactance, the cost of capacitors increases approximately as the square of the rated current so that it is usually much more economical to use capacitors whose ratings are based on the working current and to limit the voltage that can appear across their terminals by means of auxiliary apparatus.

Care must be used that the voltage rating of the series capacitor and its associated protective equipment is made high enough so the capacitor is not by-passed during working loads. To insure availability of the series capacitor during motor starting currents—when its effects are most useful—the capacitor rating must be at least 67 per cent of the greatest motor inrush current that may be imposed on the line. With protective devices set to by-pass the capacitor at a safe value of 200 per cent of this rating, the capacitor will remain in service during such transient loads.

An illustration of such an application is a 5-ohm series capacitor to be installed in a circuit on which several large motors are connected. The largest motor draws an initial starting current of 200 amperes. This produces a momentary voltage of 1,000 volts on the series capacitor. The continuous voltage insulation class of the capacitor should be 67 per cent of this, or 665 volts, while the protective gap should be set at 1,330 volts. The continuous current rating of this series capacitor should be 665 divided by 5, or 133 amperes. Quite often, as in this instance, the continuous current rating of the series capacitor is determined by the momentary current rather than the actual continuous current load in the circuit.

The device used to protect a series capacitor during a fault must not allow the voltage to rise above twice the rated value even for a short time. The capacitor must be by-passed during the first half cycle of fault current. A properly designed gap fulfills this requirement and materials can be selected to give a stable arc and a low arc drop without repetitive restriking. Under most conditions, some means must be provided for shunting this gap and transferring the arc current to another path. After the circuit current again falls to normal, the by-pass equipment must open to transfer current back again to the capacitor. This commonly is done with a thermal or magnetic contactor or by an automatic circuit breaker that closes to by-pass the gap and capacitor and opens some time after the fault has cleared to restore the capacitor to service.[1]

Where the insulation class of the series capacitor is low— for example, where 230-volt capacitor units are used and the gap must break down at 460 volts—it is not possible to set the gap for sufficiently low breakdown voltage. In such instances, a trigger circuit is used to initiate the breakdown of the gap.

Protection Against Continuous Overload. Standard series capacitors should not be used for continuous operation at an average more than 105 per cent of their rated voltage. Consequently, average working current through a series capacitor should not exceed the rated working current by more than 5 per cent. The short-circuit protective device is not designed to function at less than 200 per cent of the rated current; therefore, it is sometimes desirable to provide overload as well as short-circuit protection. The overload protective device should have an inverse time–current characteristic that can be co-ordinated with the capacitor to allow momentary overloads but not continuous ones. A thermally operated switch similar to the one previously described also can be used for this purpose.

This special type of protection usually is not warranted except on large series capacitor banks. The absence of overload protection on small distribution installations further emphasizes the need for care in choosing the continuous current rating.

Dielectric Failure Protection. Dielectric failure protection rarely is used except on large banks. This also is a feature that is sacrificed on small distribution series capacitors in the interest of simplicity and low first cost.

Dielectric protection is a means of detecting a faulted capacitor unit in a series capacitor assembly. In an unfused capacitor bank a short-circuited capacitor may sustain an internal arc which will cause gas to be generated in the unit. Continued operation will cause the internal pressure to reach a value which will rupture the case and possibly cause damage to other units and equipment. If the units are equipped with individual fuses, a fuse operation to remove a faulted unit increases the reactance of the bank and operation at the rated

current of the original bank will subject the remaining units to overvoltage. A protective device for dielectric failure protection is spring-biased to the closed position and latched open. A small solenoid mechanism is used to trip the latch when the currents become unequal in two equal branches of the capacitor. The switch stays closed and the capacitor is by-passed until the defective unit is replaced and the switch reset manually.

Details of Arrangement and Type of Capacitor Units. Series capacitors operate at line potential, and so, they must be insulated from ground for the line-to-ground voltage. This may be accomplished in a variety of ways:

1. For circuits 7,200 volts or lower the capacitor unit cases can be insulated for the line-to-ground voltage of the circuit and the capacitor cases operated at ground potential. These units can be supported on poles in conventional hanger-type brackets. In such an installation, the protective device panel should be housed in an outdoor weatherproof enclosure with insulation for the line-to-ground voltage. The protective device then can be mounted on the pole with the units it protects. The most convenient arrangement usually results when the capacitor assembly for each phase is mounted on a separate pole.

2. For circuits above 7,200 volts it is not economical to build the line-to-ground insulation into the capacitor cases. It is necessary, therefore, to support the units in a structure that is insulated from ground and operates at line potential. This usually takes the form of an insulated platform supported on poles or a set of insulated rails in a substation structure. In such an installation, the protective device is housed in a housing insulated for the voltage across the capacitor terminals. This housing has only one bushing, the housing itself serving as the other terminal. This device is mounted on the same insulated platform that supports the capacitors and operates at the line potential. Indoor-type capacitor units can be assembled in either indoor or outdoor housings. In these the protective device is built into the housing.

3. On circuits 13.8 kv and below the equipment for all three phases can be enclosed in one housing with six roof bushings. The capacitor units are mounted on insulated rails inside the housing. Usually the protective panels are mounted on the insulated rails with the capacitors.

4. On circuits above 13.8 kv the equipment for each phase is enclosed in a separate housing. The housing insulation and roof bushings are designed for the voltage across the capacitor, and the entire housing is supported on insulators designed for the line-to-ground voltage of the system.

Switching Accessories. A series capacitor acts as a voltage regulator that is entirely automatic in its operation, and thus there is no occasion to remove it from service except for inspection and maintenance. If it is possible to de-energize the line for this purpose, no switching equipment need be associated with the capacitor.

If it is desirable to remove a series capacitor without interrupting service over the circuit, it can be by-passed with a disconnecting switch as shown in Figure 1. Such a switch must discharge the capacitor and carry the line current when closed and must transfer current back to the capacitor when opened. To prevent burning of the switch contacts, the switch must be equipped with the arcing horns. The switch chosen should have a voltage rating of the line voltage of the circuit and a current rating equal to or greater than the full-load current of the circuit.

In addition to the by-pass switch, two disconnecting switches are required to isolate the capacitor from the line as shown in Figure 1. These switches should have the same rating as the by-pass switch.

SELECTION OF SERIES CAPACITOR

Resistance and inductive reactance of the distribution circuit must be known before the improvement in voltage realized for different sizes of series capacitors can be calculated. Both of these quantities can be obtained from any engineering handbook. Impedance of transformers usually is given on the name plate or can be obtained from the manufacturer.

The problem of computing the circuit resistance and reactance may be complicated somewhat if there are one or more transformers in the circuit between the substation bus and the capacitor. In such an instance, all constants of lines and transformers must be reduced to their equivalents at the voltage of the section on which the series capacitor is to operate.

Table I. Table of Standard Series Capacitor Unit Ratings*

Rated Voltage	Rated Kva	Reactance, Ohms	Rated Current, Amp
230	7½	7.05	32.6
330	13	8.38	39.4
400	15	10.7	37.5
425	15	12.0	35.3
460	15	14.1	32.6
485	15	15.7	30.9
515	15	17.7	29.1
575	15	22.0	26.1
660	15	29.0	22.7
705	15	33.0	21.3
750	15	37.5	20.0
815	15	44.5	18.4
895	15	53.5	16.8
1,000	15	66.5	15.0
1,200	15	96.0	12.5
1,320	15	116.0	11.4
1,470	15	144.0	10.2
1,600	15	171.0	9.37
1,740	15	204.0	8.62
1,920	15	246.0	7.81
2,200	15	323.0	6.82
2,400	15	384.0	6.25
2,640	15	465.0	5.68
2,900	15	561.0	5.17
3,180	15	674.0	4.72
3,480	15	808.0	4.31
3,750	15	938.0	4.00
4,160	15	1,160.0	3.60
4,800	15	1,540.0	3.12
7,200	15	3,460.0	2.08
7,960	15	4,230.0	1.88

* Table based on proposed standards of the National Electrical Manufacturers Association.

Reactance. When the circuit constants and load are known, the improvement in voltage that can be realized for different values of X_c can be calculated using equation 1. The value of X_c that is chosen should be the

smallest value that will give satisfactory regulation. It should not be made greater than X_L except under special conditions as where over-compensation has been proved definitely to be desirable.

Current. As explained in "Protection During Line Fault," the rms value of the greatest momentary load current never should exceed 150 per cent of the current rating of the capacitor. The current rating of a series capacitor should be chosen so that the following limits never are exceeded:

Continuous Current. The sustained current should not exceed 110 per cent of the capacitor rating and the average current over any 24-hour period should not exceed 105 per cent of the capacitor rating.

Momentary Current. The rms value of the greatest momentary load current should not exceed 150 per cent of the capacitor rating.

Table I gives the standard series capacitor unit ratings. These can be combined to obtain the desired series capacitor reactance and total continuous current rating as follows:

1. Determine desired series capacitor reactance and continuous current rating.

2. Multiply the rated series capacitor current by the desired reactance to obtain the rated working voltage.

3. Select a capacitor unit from the table having an equal or next higher voltage rating.

4. From the table read the reactance of the unit selected and divide this by the desired series capacitor reactance. This gives the number of units required. If it does not come out a whole number use the next larger whole number of units.

Example Application. Given: a 4,800-volt (line-to-line) distribution circuit with a full load current of 100 amperes and a maximum momentary current of 170 amperes at 60 per cent power factor. The circuit is fed from a 13.2 kv bus through three 500-kva 2.6-per-cent reactance transformers. It consists of a 3-wire line five miles long. The conductors are 0000 cables and are spaced $21^3/_4$ inches between centers on horizontal cross arms.

Find: series capacitor that will reduce the voltage regulation peaks to eight per cent.

Transformer reactance per phase $= (4{,}800)^2 \times 0.026/(500 \times 1{,}000)$
$= 1.20$ ohms
Spacing phase 1 to phase 2 $= 21^3/_4$ inches
Spacing phase 2 to phase 3 $= 21^3/_4$ inches
Spacing phase 1 to phase 3 $= 43^1/_2$ inches
Effective spacing $= \sqrt[3]{21^3/_4 \times 21^3/_4 \times 43^1/_2}$
$= 27.4$ inches
The reactance is found from tables in an engineering handbook to be 0.595 ohm per mile.
Line reactance $= 5 \times 0.59$
$= 2.95$ ohms
Total circuit reactance $= 1.20 + 2.95$
$= 4.15$ ohms
Resistance of conductors $= 0.30$ ohm per mile.
Resistance of transformer $= 0.5$ ohm per phase.
Total circuit resistance $= (5 \times 0.30) + 0.50$
$= 2.00$ ohms
The maximum voltage drop without the series capacitor $=$
$(170 \times 2.00 \times 0.6) + (170 \times 4.15 \times 0.8)$
$= 204 + 565$
$= 769$ volts

$$\text{The regulation without the series capacitor} = 100 \times \frac{679}{4{,}800/1.732}$$

$= 27.7$ per cent
Voltage drop at 8-per-cent regulation $= (4{,}800/1.732) \times 0.08 =$
222 volts

Using equation 1

$$222 = (170 \times 2.00 \times 0.6) + 170(4.15 - X_C)(0.8)$$

From which

$$X_C = 4.02 \text{ ohms}$$

Assume that during the simultaneous operation of two spot welders on this circuit the momentary current rises to 170 amperes and all other times it is less than 100 amperes. The capacitor must have a continuous current rating of 170 divided by 1.5, or 113 amperes, if its momentary current rating is to be limited to 150 per cent.

The rating of the series capacitor required for each phase now is determined to be 4.02 ohms, 113 amperes. With this information a standard series capacitor unit can be chosen from Table I.

Capacitor rated working voltage $= 113 \times 4.02$
$= 454$ volts.

From Table I the next higher voltage rating is selected which is 460 volts. It is seen that each 460-volt unit has a reactance of 14.1 ohms.

$14.1/4.02 = 3.52$

The nearest even number of units above 3.5 is 4 so the preferred rating of the series capacitor for this application will be four 460-volt units per phase and the nearest rating of the series capacitor will be 3.52 ohms at 130.4 amperes continuous current and 195.6 amperes momentary load.

Special Problems. One of the most frequent causes of trouble has been the failure to select the basic rating of the series capacitor sufficiently high with respect to instantaneous load currents so as to avoid the operation of protective devices by these momentary loads.

Care must be used to avoid boosting transformer voltages into the nonlinear range where resonance effect may be troublesome.

The effect of a series capacitor on the operation of an electric system cannot be predicted without a detailed study taking into account all the possible loads on the system in all their combinations. Certain loads, particularly those that draw currents containing large harmonic or subharmonic components, may be resonant with the capacitive reactance under certain conditions and improper operation will result. If such difficulties are encountered, they can be corrected by changing the size

of the capacitor or, in extreme instances, by shunting the series capacitor with a resistance. It should be understood that any installation may require some initial adjustment.

The principal problem in the operation of circuits with series capacitors arises in starting large induction or synchronous motors. Such a system may be resonant at some speed less than synchronous. This is particularly true if the motor starting load predominates. Under these conditions the motor will come up to partial speed and continue to rotate at this reduced speed. Trouble of this nature can be eliminated by shunting the series capacitor with a resistance. This is a particularly good method because at system frequency little of the current is by-passed but at the lower frequency of resonance sufficient current is by-passed to prevent resonant effects. A series capacitor installed on a system that has a motor larger than ten per cent of the full-load circuit kilovolt-amperes should have a shunt resistor. If this resistance is not more than ten times the capacitive reactance the chances of difficulty are remote.

If the tranformer primary voltage is boosted substantially, as, for example, when energizing the line, or when the load suddenly increases, some saturation may take place which results in ferroresonance. These conditions, like those for motor starting, can be corrected by shunting the series capacitor with a resistance of the order of ten times the capacitor ohms. Transformer saturation also may occur if the load current drops sharply permitting the series capacitor to produce a large d-c component in the transformer primary. This is also subject to correction by a resistor permanently connected in parallel with the series capacitor.

It must be recognized that the results to be expected with a series capacitor are not as predictable as with a shunt capacitor, nor can series capacitors be applied with the same ease as shunt capacitors, or with the same guarantee of results. Shunt capacitors simply draw a leading current of known magnitude and are unaffected by other equipment on the system. Series capacitors, however, modify the characteristics of the entire circuit and only can be dealt with successfully in terms of system performance.

In making an economic analysis comparing the cost of series capacitors, with other solutions such as new lines or raising voltage levels, the entire cost of the series capacitors should include the necessary careful study of the application, cost of the protective equipment, and probable field tests.

The use of series capacitors has made possible the solution of many difficult problems associated with voltage dips, problems that could not have been solved in any other way.

REFERENCE

1. New Series Capacitor Protective Device. **R. E. Marbury, J. B. Owens.** AIEE *TRANSACTIONS*, volume 65, 1946, March section, pages 142–6.

Simulated Electron Tube

A "make-believe" model that tests in one day electronic tube designs which otherwise require three months to try out is aiding engineers of the Westinghouse Electric Corporation in their research on tubes for television, radio, and radar.

The simulated electron tube consists of a very thin sheet of rubber stretched across a frame about the size of a small dining room table. BB-shot-sized bronze balls simulate electrons; hills and valleys in the rubber simulate electric voltage; and wooden blocks act as tube elements.

Proper arrangement of the hills and valleys directs a ball and controls its velocity. Measuring the time it takes for the ball to roll from one part of the table to another, enables engineers to calculate the speed of actual electrons in a tube. This determines the voltage needed for the particular part of the tube.

To find the proper spacing and optimum shape of tube elements, wooden reproductions for various shapes and sizes of cathodes, grids, or anodes are used. They help research men to find the arrangement that gives the best focusing of electrons.

The model, which can produce approximate replicas of most kinds of tubes, permits checking the internal design of a tube in one day as compared with three months by the trial-and-error method. Moreover, checking minor design changes in an electrode, which used to require an entire day, now can be done in five minutes.

The ENIAC

J. G. BRAINERD
FELLOW AIEE

T. K. SHARPLESS
ASSOCIATE AIEE

The ENIAC is the only electronic large-scale general-purpose digital computing device now in operation. Its speed of operation compares favorably with other electric and mechanical computers. Developed under wartime pressure, it has been of value not only in producing results but in pointing the way toward improvements for future designs.

THE ENIAC (electronic numerical integrator and computer) is a large-scale device, adapted to problems requiring a large amount of work for their solutions, and particularly to problems which involve the repetition of a large number of similar types of computations to achieve a result. The ENIAC does not reach a point of practical usefulness until applied to a problem which is such that a large amount of repetitious computation is necessary to obtain numerical answers. Such problems often involve the solution of differential equations, the evaluation of series, or the preparation of mathematical tables. For example, the equation:

$$\frac{d^2y}{dt^2}+\epsilon(1+k\cos t)y=0$$

(where ϵ and k are parameters) is one which arises in several electrical problems, and has extensive use elsewhere. To solve it for values of $\epsilon=1, 2, 3, \ldots 10$ and $k=0.1, 0.2, \ldots 1.0$ requires 100 results, each of which is a table of y versus t. Each separate complete solution applies to one value of ϵ and one of k. To get this, the equation is solved by a corresponding difference equation, and if $\Delta t=0.0004$, then about 7,850 "lines" are called for in the range $0<t<\pi$. In carrying out each line of work, approximately 10 multiplications and many more additions and subtractions were needed. Thus, in one solution of the equation for the given values of ϵ and k and for the range $0<t<\pi$, there were 78,500 multiplications and many more additions or subtractions. Multiplying these by 100 (as this number of complete solutions was desired), there resulted 7,850,000 multiplications and many more additions and subtractions. The work of obtaining two separate solutions for y in each instance, corresponding to two different sets of initial conditions, required 15 continuous hours of ENIAC operating time. This included making a test run after every 5 regular runs, thus increasing the work outlined by 20 per cent. Ten digit numbers were used throughout, (the reason for using such "large" numbers is discussed briefly later) and each result was recorded for $t=0.0, 0.1, 0.2, \ldots$ up to $t=3.14$ after which the values for $t=3.1408, 3.1412, 3.1416, 3.1420,$ and 3.1424 were added to enable values of the results at π to be obtained accurately by interpolation. This brief summary of machine operations and time used in solving an actual problem indicates the orders of magnitudes of these two items as they are related to the ENIAC.

Electrical engineers in the United States have had a major interest in the development of large-scale computing devices. Probably the most extensively used such instrument in the world is the a-c calculating board, but although this is a large scale device it is hardly a general purpose computer even though it has been used by Kron of the General Electric Company in such problems as solving certain partial differential equations.

Another large-scale device is the differential analyzer, which originated in the electrical engineering department of Massachusetts Institute of Technology. Of the five now in the United States, two are at Massachusetts Institute of Technology, one at the Moore school of electrical engineering of the University of Pennsylvania, and one at the General Electric Company.* Differential analyzers have been used extensively in connection with machinery, stability, and similar problems, as well as in many fields outside electrical engineering, and all the analyzers now in the United States are in almost continuous use. The primary purpose of differential analyzers is to solve sets of ordinary differential equations, and, although they have been put to numerous other uses, this remains their prime objective.

Among other large scale computing devices are the Bell Telephone Laboratories relay computer and the International Business Machines automatic sequence controlled calculator at Harvard University.[1] Particular note should be made of these machines, because in some respects it may be said that operations carried out by

J. G. Brainerd is professor and T. K. Sharpless is research engineer at the Moore school of electrical engineering of the University of Pennsylvania, Philadelphia, Pa.

Considerable credit should go to Colonel Paul N. Gillon, Colonel Leslie E. Simon, and Major H. H. Goldstine of the Army Ordnance Department for their backing of the project, which was carried out under an Ordnance Department research and development contract. The ENIAC was developed and built at the Moore school of electrical engineering of the University of Pennsylvania. J. P. Eckert, Jr., was chief engineer and was primarily responsible for design; Doctor J. W. Mauchly was research engineer as was the junior author of this paper (Doctor Mauchly had much to do with the original proposals); and numerous others contributed to the development including particularly the following engineers: Arthur Burks (A '42), Joseph Chedaker (A '43), Chuan Chu, James Cummings, Leland Cunningham (astronomer whose war work was in large-scale computations), John Davis, Harry Gail, Robert Michael, Frank Mural, and Robert Shaw. The senior author of this paper was the project supervisor.

* The fifth is substantially a duplicate of the one at the Moore school, and is in the Ballistic Research Laboratory of the Army Ordnance Department, Aberdeen Proving Ground, Md.

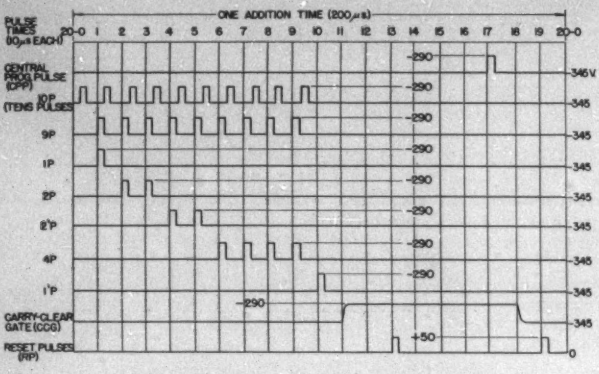


Figure 1. Pulses used in the operation of the ENIAC

the ENIAC by electronic methods are performed in them by mechanical means. (The converse is not necessarily true, as will be explained subsequently.)

Another, and important, large-scale general-purpose computing "unit" is a group of business machines such as those of the International Business Machines Corporation. These devices can be used for addition, subtraction, multiplication, recording, and so forth, and by transferring punched cards from one to another, the sundry numbers in a problem can be operated on as desired. The Watson computing laboratory at Columbia University contains such a unit, as do numerous other places. Engineers might be interested to know there are units at the General Electric Company and in engineering departments of the Massachusetts Institute of Technology and University of Pennsylvania.

TERMS

A discussion of some terms used in connection with computing devices will simplify a description of the ENIAC:

Large-Scale. Although the afore-mentioned large-scale devices all require a moderately large room to contain them, size is not necessarily an accompaniment of large scale. Indeed, one of the purposes behind new electronic machines now under development is to reduce physical size and complexity. Large-scale refers rather to the magnitude of the problems which may be placed on a device so labeled. A desk calculator of any of the common types is a small-scale device; the ENIAC (and others) which without human intervention may perform thousands of additions, multiplications, and so forth in the proper sequence and with numbers evolved in the operations as the work proceeds, is a large-scale device.

General Purpose. A general purpose machine is one which will handle many types of problems, in contrast with specialized devices. A desk calculator is a general-purpose small-scale machine; an a-c calculating board is a special-purpose large-scale calculator.

Continuous (Analogue) Versus Digital. A continuous variable or analogue type of computer is one such as a differential analyzer, where the angular displacements of rotating shafts or other devices give direct measures or analogues of results at each instant. The continuous motions of the shafts are to be contrasted with a desk calculator where continuous variation is impossible because adjacent keys in a column differ by a unit, and it is not possible to go between the values given by unit change in the right-hand column. The distinction between analogue and digital devices does not imply that they are to be applied to separate fields. A large-scale general-purpose digital device such as the ENIAC and others for most practical purposes can differentiate and integrate by using extremely small intervals of the independent variable ($\Delta t = 0.0004$ was cited in a foregoing example). It is true that the independent variable will not change uniformly, but rather in steps; nevertheless, the steps may be taken so small as to make over-all errors small. A-c calculating boards, differential analyzers, slide rules, and so forth, are continuous variable devices; most development now under way on large-scale computers is confined to digital types. The reason for this is that higher accuracy is obtainable with the digital device. For example, the ENIAC can handle numerical quantities of 10 significant figures and with a minor change can handle 20 significant figures. On the other hand, differential analyzers or other analogue machines yield at best 4 or 5 significant figures, and to increase this would require complete and revolutionary design changes.

Electronic Versus Mechanical. By an electronic computing device is meant one in which the arithmetic and control procedures are performed in the machine by electronic circuits. The ENIAC is the only electronic large-scale general-purpose computer now in operation. In contrast, mechanical means such as relays are used in other existing large-scale digital instruments, and the basic arithmetic device in all differential analyzers is the mechanical integrator. A-c calculating boards are electric devices; the word electronic is used because the new electric computers (ENIAC and those under development) use electron tube circuits extensively.

Amplitude Versus Step Mechanisms. The distinction to be attempted here between amplitude and step mechanisms has to do with the internal operation of calculators and not with the question of continuous (analogue) versus digital machines. An amplitude mechanism is one in which a result is indicated by the amplitude of some quantity, as, for example, the voltage on a capacitor. The voltage may be read as closely as possible, or the device might be used in a digital system in which any voltage from 7.5 to 8.5 indicated the number 8. A step mechanism is, like a relay, one characterized by an on–off or an open–closed state. If ten relays are arranged in a column and labeled 0, 1, 2, . . . 9, then if all are open except that labeled 8, the number 8 is indicated. The definiteness of on–off or open–closed devices like relays and certain tube circuits has led to their use almost exclusively in large-scale digital computers. A basic elementary circuit in the ENIAC is a pair of tubes (trigger circuit) so arranged that when one (number 1) is conducting the other (number 2) is not. If, for any cause, number 2 becomes conducting and number 1 not, a reversal has occurred. This reversal can be

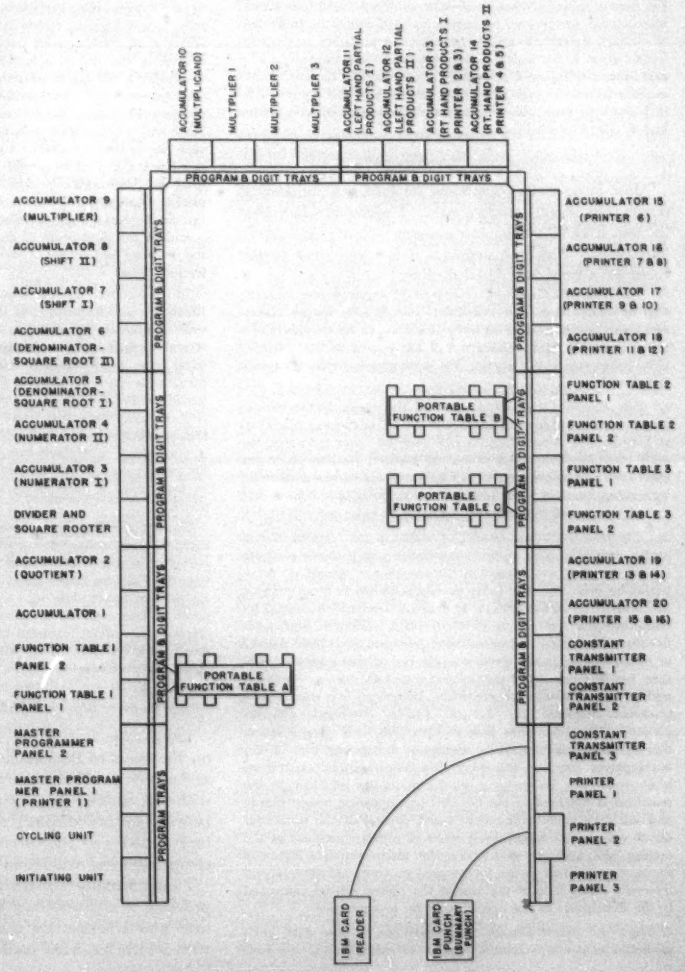
made to correspond to the change from open to closed or conversely of a relay, or, in more general terms, from a normal to an abnormal state.

Synchronous Versus Sequential. If as soon as one operation such as a multiplication is completed a signal is given which initiates immediately the following operation, a calculator is said to have sequential operation. An individual operating a desk calculator would work on a sequential basis. If on the other hand no operation can begin except at an integer multiple of some fixed time interval after a previous operation has begun, the calculator is said to work synchronously. The ENIAC is of the latter type, its operation being controlled by a group of pulses which are repeated every 200 microseconds. A new operation can start only at the beginning of one of these 200-microsecond intervals.

Series Versus Parallel Operation. A large-scale digital calculator is said to have parallel operation if two or more arithmetic operations (two additions, or an addition and a multiplication) can be carried out simultaneously. It has series operation if no two arithmetic processes can be carried out at the same time. The ENIAC has a limited amount of parallel operation, but because of the high speed of the electronic machines the tendency in new development is toward series operation wherever that mode reduces complexity.

Figure 2. ENIAC floor layout

Initiating unit—Controls for power, operation controls
Cycling unit—Source of pulses used in operation of ENIAC; name is derived from cycle of pulses shown in Figure 1 and does not refer to cycles of arithmetic operations
Master programmer—Controls the cycles of arithmetic operations and performs other programming functions
Function table panels—Used in conjunction with function table to call up at high speed numbers "set" in function table
Accumulator—Performs additions and subtractions, stores results, and so forth
Divider—Performs divisions and also can be used to take square roots
Multiplier—Performs multiplications
Constant transmitter—Receives at low speed information from the input device (an International Business Machines card reader, as indicated) or other device, and supplies this information at high speed when called for (note that the input device is at what appears to be the next to the last position rather than at the "beginning" of the ENIAC; this is of no significance). The constant transmitter also has a limited capacity for storing numbers set on switches on its front panel
Printer—Receives at high speed results to be recorded and transmits them to the relatively slow-speed output device (an International Business Machines card punch as indicated)
Digit trunks—Special transmission lines into which connection can be made to transmit numbers from one part of the ENIAC to another
Program trunks—Special transmission lines into which connection can be made to transmit program orders (electric pulses) from one part of the ENIAC to another
Trunk from cycling unit—Permanently connected to other units to which it supplies the group of pulses shown in Figure 1 every 200 microseconds when ENIAC is in continuous operation


ACCUMULATOR 10 (MULTIPLICAND)
MULTIPLIER 1
MULTIPLIER 2
MULTIPLIER 3
ACCUMULATOR 11 (LEFT HAND PARTIAL PRODUCTS I)
ACCUMULATOR 12 (LEFT HAND PARTIAL PRODUCTS II)
ACCUMULATOR 13 (RT HAND PRODUCTS I PRINTER 2 & 3)
ACCUMULATOR 14 (RT. HAND PRODUCTS II PRINTER 4 & 5)
PROGRAM & DIGIT TRAYS
PROGRAM & DIGIT TRAYS
ACCUMULATOR 9 (MULTIPLIER)
ACCUMULATOR 8 (SHIFT II)
ACCUMULATOR 7 (SHIFT I)
ACCUMULATOR 6 (DENOMINATOR - SQUARE ROOT II)
ACCUMULATOR 5 (DENOMINATOR - SQUARE ROOT I)
ACCUMULATOR 4 (NUMERATOR II)
ACCUMULATOR 3 (NUMERATOR I)
DIVIDER AND SQUARE ROOTER
ACCUMULATOR 2 (QUOTIENT)
ACCUMULATOR 1
FUNCTION TABLE I PANEL 2
FUNCTION TABLE I PANEL 1
MASTER PROGRAMMER PANEL 2
MASTER PROGRAMMER PANEL 1 (PRINTER 1)
CYCLING UNIT
INITIATING UNIT
PROGRAM TRAYS
PROGRAM & DIGIT TRAYS
PROGRAM & DIGIT TRAYS
PROGRAM & DIGIT TRAYS
PROGRAM & DIGIT TRAYS
PROGRAM & DIGIT TRAYS
PORTABLE FUNCTION TABLE A
PORTABLE FUNCTION TABLE B
PORTABLE FUNCTION TABLE C
ACCUMULATOR 15 (PRINTER 6)
ACCUMULATOR 16 (PRINTER 7 & 8)
ACCUMULATOR 17 (PRINTER 9 & 10)
ACCUMULATOR 18 (PRINTER 11 & 12)
FUNCTION TABLE 2 PANEL 1
FUNCTION TABLE 2 PANEL 2
FUNCTION TABLE 3 PANEL 1
FUNCTION TABLE 3 PANEL 2
ACCUMULATOR 19 (PRINTER 13 & 14)
ACCUMULATOR 20 (PRINTER 15 & 16)
CONSTANT TRANSMITTER PANEL 1
CONSTANT TRANSMITTER PANEL 2
CONSTANT TRANSMITTER PANEL 3
PRINTER PANEL 1
PRINTER PANEL 2
PRINTER PANEL 3
IBM CARD READER
IBM CARD PUNCH (SUMMARY PUNCH)

Decimal Versus Binary. This heading lists two of the large number of possible number codes which can be used in connection with a digital machine. In the ENIAC numbers appear in the usual way they are used, and this representation is called a decimal one. On the other hand, the open-closed or on-off characteristic of relays, certain tube circuits, and the like, has led to extensive consideration of the use of the binary, or base two, system. In this case a number would be "translated" from its common expression in the decimal system to its expression in the binary system of numbers. It would be retained in this latter system, and most or all operations would be performed on it in this system, until a desired result is achieved, in which instance it would be translated from the binary to the decimal system either before or after recording. Other number systems besides the binary may be considered—the choice of a system to use internally is determined by saving in equipment, simplification in circuits, magnitude and complexity of translation equipment, weight given to simplicity of understanding for maintenance men and other nontechnical personnel, and so forth. As the ENIAC uses the decimal system, no further discussion of this topic will be included here, except to note that other systems such as the binary and the biquintic are in use.

MACHINE COMPONENTS

Most large-scale computing devices can be broken down into several components. Despite the fact that in the ENIAC these components are mixed almost inextricably with one another, it is convenient to use them for a brief functional outline.

1. *The Arithmetic Component* consists of 20 accumulators for addition or subtraction, one multiplier, one divider square rooter, and three function tables on each of which can be set values of a known function to be called up in the course of the solution. (The calling up is arithmetic; the settings are memory as next described.)

2. *The Memory Component* consists of the same 20 accumulators, any one of which can be used to "hold" or "store" a number so long as that accumulator is not used for other purposes, the same three function tables which are memory devices yet at the same time arithmetic, and finally an unlimited memory obtained by sending numbers to be remembered to the output device, and having them available for recall through the input device.

3. *The Control Component* may be considered to consist of two parts: control of basic operations without regard to the problem on the machine, and control of the sequence of operations for a particular problem. The latter usually is known as programming and is achieved on the ENIAC by external connections inserted by hand between the panels of the various arithmetic and other devices. In order to carry out such processes as to have a cycle of operations repeated, another cycle begun and repeated, and then the first one again carried out a certain number of times, and to do many other programming jobs, there is a master programmer available for control. Other large-scale general-purpose digital machines now in operation have programming done automatically, and the electronic computers now under development likewise will have this feature. The control of basic operations, independent of the particular problem on the machine, is obtained in the ENIAC (disregarding power supply and auxiliary equipment controls and control of the numerous direct voltages for tubes) by a series of pulses generated at the cycling unit and repeated every 200 microseconds. Figure 1 shows the group of pulses so required in each 200-microsecond interval. Some idea of the uses of the pulses will be contained in the description of the operation of an accumulator.

4. *Input and Output Devices.* The questions of how data, such as initial values of variables, values of parameters, are supplied to a device such as the ENIAC, and how results are to be taken out of the machine, are to a large extent independent of the computing device. Thus, data may be recorded originally on a punch tape, on a magnetic tape, on punch cards such as are used in business machines, or otherwise, and an appropriate mechanism devised to insert into the computing machine the electric or other type of signals needed to inform the machine of the numbers being supplied to it. Likewise, a result which it is desired to record may appear somewhere in the machine, and this result may be brought out to a mechanism which will translate the machine result (given by indications in certain circuits in the case of the ENIAC) to a punch tape, a magnetic tape, an electric typewriter, a punch card, an indication on a film, or other medium. It is interesting to note that the speed at which input and output devices operate may be so low, relatively, that, on occasion, they may be the limiting factor in determining the over-all time in which a problem can be done. This limitation is particularly evident in the case of a high-speed electronic computer such as the ENIAC, and might be illustrated by reference to the problem cited previously. The equation there given was solved on the machine 100 times, and in each instance it was solved for some 7,850 values of t, differing in steps of 0.0004 from zero to π. If each one of these results for a given set of values of ϵ and k were tabulated, the machine would obtain the solution and then wait until the slow-speed recording of the previous solution was completed. Actually, every hundredth result was recorded, and thus the machine ran through 100 lines while the output device was recording the final result of the previous 100 lines. In this way the machine had plenty of work to do during the time required for recording.

In the ENIAC, input and output are by International Business Machines punch cards, and there are other input methods as well. Consider, for example, the case in which it is desired to record a result in the machine. This result, appearing in electrical form, is translated to a set of mechanical relays which, in turn, cause an International Business Machine card punch (usually called the "printer") to punch on a card the result. This is a relatively long-time procedure, but meanwhile the ENIAC is proceeding without interruption, unless it should happen that it produces a new result for recording before recording of the first one is completed, in which instance the ENIAC pauses in its work until it receives an appropriate signal from the card punch.

Current developments in large-scale general-purpose digital computing devices are devoted to a considerable extent to obtaining speedier input and output mechanisms. It may be noticed that the function tables mentioned in "Memory" may be used to insert arbitrary data into the ENIAC at high speed, and in addition there are built-in facilities of limited extent in the ENIAC (in the unit called "constant transmitter") for inserting at high speed numbers (such as π) which frequently may be used in a particular problem.

BASIC CHARACTERISTICS

Large-scale computing devices often are compared on the bases of flexibility, accuracy, speed, reliability, and capacity. These characteristics are so intertwined with one another that no absolute clean-cut distinction between factors affecting each can be maintained, but in a broad way they serve as an introduction to the comparison and evaluation of the large-scale machines.

Fundamentally the desideratum is to solve a given problem to the accuracy desired in the least possible time and at minimum cost. "Time of solution" is a term which has been used in numerous ways; it may

include all the time from first tackling the problem with pencil and paper to final tabulation of results obtained on the computing device. But often "time of solution" means machine time (interval the machine is devoted to the problem). It also has been used to denote operating time which is the time the machine actually operates in solving the problem and excludes setup time, if any, close-down time, and time for major maintenance work, if any. However, with regard to the basic objective it is over-all time—a useful but not precise interval—which is of interest.

Flexibility. In a digital machine flexibility means that the device or devices for carrying out arithmetic processes may be interconnected in arbitrary fashion, or ordered to perform operations in arbitrary sequence, so that there would be no limitation on the operation to be performed next on a given number in the machine. This flexibility is to be contrasted with a machine permanently "wired" so that it is restricted to variations of one problem.

In a more general sense flexibility denotes the existence in a machine of a device or devices for carrying out the usual arithmetic processes: addition, subtraction, multiplication, division, differentiation, and integration, as well as it denotes flexibility of potential arrangements. Digital machines such as the ENIAC are described as general purpose machines because they are both flexible as to arrangement, and have devices for all the arithmetic processes, including differentiation and integration, which are carried out by approximate methods so accurately that they suffice for most purposes.

Virtually all practical problems requiring numerical solutions come within the scope, but not necessarily the capacity, of the general purpose digital computers. There is a lower limit of complexity or quantity below which it does not pay to use a *large-scale* general-purpose computer, but this practical limitation should not be allowed to shadow the fundamental fact of the preceding sentence: virtually all practical problems requiring numerical solutions come within the scope, but not necessarily the capacity, of the general purpose computers.

Computers such as a-c calculating boards and differential analyzers are not general purpose devices, and despite the extension of their application to problems not originally contemplated when they first were devised, they remain substantially specialized and not flexible in the sense that term is used here.

Accuracy. Most continuous variable or analogue computers give results which may be accurate to three or four figures; the accuracy depends on the problem under solution, the part of the solution considered, and other factors, as well as on the device. Many results from differential analyzers are obtained in the form of curves. A-c calculating boards yield answers obtained by instrument readings. In contrast, numerical solutions accurate to five or more figures sometimes are

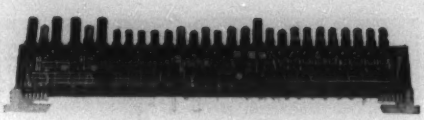


Figure 3. A decade counter

required in practice. It is desirable that new tables of mathematical quantities be given to several significant figures beyond current use to allow for future needs which usually are more exacting than existing ones. Computations which involve many differences of nearly equal numbers require many more significant figures in the numbers than will be obtained in the result. Numerous other examples of the desirability of high accuracy may be cited. For these reasons, and the added fact that to help justify its existence a large-scale general purpose computing device like the ENIAC definitely should increase accuracy over such "old-time" (in the era of large-scale computers) devices as the differential analyzers, most large-scale general-purpose digital computers deal with numbers which may seem outsize to engineers, but which actually are not. In the ENIAC, provision is made for using 10-digit numbers (as in the case of simple 10-column desk calculators) in almost all parts of the machine. This figure was chosen after a rough study of a particular differential equation which had to be solved many thousands of times during the war, and the choice was made to insure that 5-figure accuracy was found in the results. There are definite reasons why the accuracy of the solution of a differential equation (or other mathematical form) may decrease radically when handled by digital methods; a simple example not associated with any computing device or with a differential equation would be a column of 1,000 numbers to be added (it will be recalled that in the ENIAC many thousands of operations may take place in obtaining a solution). If each number is given to 11 significant figures, and the decimal point is at the same position in all of them, then disregarding the 11th figure in each case and carrying out the addition would result in an error of the order of magnitude of 500, the 5 appearing in the eighth digit position. While such an error in simple addition might not appear directly in the ENIAC because provision for round-off is made, nevertheless, problems such as differential equations can involve processes which result in decreased accuracy (assuming the machine operates correctly) because of the way the machine solves the problem.

The "floating decimal point" which may improve accuracy for a fixed size of number to be used in a machine or, conversely, may decrease the size of number required for a given accuracy is a feature not included in the ENIAC.

Speed. Setup time is the time required to arrange the interconnections for the particular problem at hand.

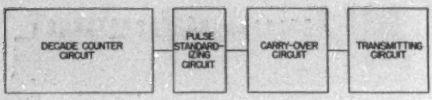


Figure 4. Block diagram of decade unit

In machines with automatic programming this is done by instructions given by the input device as the problem proceeds. In the ENIAC, interconnections (not including those which are the same for all problems and are built in) are made by hand, small patch cords being inserted at appropriate points in the machine and in the trunk system which extends around the front of the machine. The time required for this depends on the problem and the experience of the operator. It ranges from 30 minutes to a full day, and in this time the machine is not in operation, hence setup time is wasted so far as use of the machine is concerned.

The speed with which arithmetic operations are carried out is given by Table I, which shows the times required. This is an extremely important item, for it shows the great speed with which the ENIAC works in solving a problem. Take, for example, the time required to multiply two 10-digit numbers: it is approximately 3 milliseconds, or the speed is approximately 300 such multiplications per second. Now consider a problem requiring 1,000,000 multiplications. If there were no delays such as might be caused by slow-speed input and output equipment, this might be accomplished in an hour. Allowing 100 per cent leeway for all other operations except input and output (note that addition and subtraction are much faster than multiplication), this means that the problem might be solved in 2 hours, plus the time delay resulting from waiting for the input and output devices to complete their operations—if the latter operated very few times this would be negligible; if the problem required frequent operation of these devices this might amount to hours.

In connection with development work now under way on electronic large-scale general-purpose computing devices, increase in speed of arithmetic operation is not considered of major importance, although new machines may have speeds greater than those of the ENIAC by factors from slightly more than one to approximately ten.

It is interesting to note that the high speed of operation of the ENIAC makes less important the mathematical work which is often an intensive part of the preparation of a problem for solution. If the problem, for example, is to be hand-computed by a computing pool, it is often desirable and sometimes essential, that the solution be obtained by the most efficient method—quickly converging series, a special method of solution, maximum interval consistent with accuracy so that arithmetic work is minimized, and so forth. If this same problem were to be solved on the ENIAC, a saving of 50 per cent in solution time well might be negligible and the many days' work by high-quality personnel which often is put into such problems before any arithmetic work is done possibly might be cut down.

Reliability. There is no point in saying that a problem involving one million multiplications of 10-digit numbers can be carried out in two hours if the machine will have a breakdown before the problem is completed (although storage of results at regular intervals may save work up to the end of the interval preceding the trouble). The ENIAC was in numerous respects a pioneering device. Although several thousands of vacuum tubes have been used in a single network previously (this excludes systems such as the telephone system which uses many more tubes but in which a tube failure does not render the entire system inoperative) it is probable that no single device has had the 18,000 tubes which appear in the ENIAC. Since first use of the ENIAC much experience has been gained in operation and maintenance, and much of this bears directly on the question of reliability.

For 11 months the machine was in active use by Army Ordnance Ballistics Research Laboratory personnel at the Moore school. During this time a log book was kept listing all shutdowns and troubles encountered in the course of running problems. In this period of time the removal rate for tubes was one per 20 hours. In other words, 400 out of 18,000, or somewhat less than two per cent, of the tubes caused trouble during the course of the 8,000 hours of the study. It should be pointed out that the ENIAC was put into action immediately upon completion because of the urgency of some of the problems awaiting its operation. As a result there was no opportunity for a real "run in" period. This fact accounts for a rather high incidence of intermittent troubles resulting from bad soldered joints. There are some 500,000 soldered joints in the machine. (Besides its electronic circuits ENIAC includes a number of mechanical and electromechanical parts such as ventilating fans, protective relays, input and output relays, and punch card reader and punch. This equipment totals about ten per cent of the total components of the complete machine.) After the first few weeks of operation the practice of keeping power supplied continuously to the heaters of the vacuum tubes was followed as it was discovered that each shutdown resulted in two or three tubes failing. Power failures cannot be prevented

Table I. ENIAC Operating Speed

Operation	Time Required, Microseconds	Speed, Operations Per Second
Addition or subtraction	200	5,000
Multiplication of two 10-digit numbers	2,800	360
Calling up of the value of a function (from function table)	1,000	1,000

entirely and several occurred during the 11 months.

The method used for checking the results of a problem was generally as follows. Before and after each run of a problem test problems were run. In addition, many problems were checked within themselves, that is, certain terms or parts of these problems always must equal some constant such as one. Thus a check operation may be programmed comparing this part to one. The machine may be stopped automatically if this comparison is not right or the results may be printed for the operator to examine. Besides these precautions, each problem usually was run twice and the results compared.

Of the time that the ENIAC might have been actually computing, about 50 per cent was unproductive. Approximately half of this time was used for setting up the problem—connecting patch cords, setting switches, and checking these operations. This time is longer than is the rule now since operators and coders of problems were unfamiliar with the job and also because the problems solved initially were of extremely complex nature. The other half of this unused machine time was spent in maintenance and repairs.

A brief summary of the classes of failures requiring repairs follows:

1. Vacuum tube and electronic circuit component failure. These accounted for 20 per cent of the repair and maintenance time.

2. Circuit failures of mechanical nature such as bad solder joints, broken wires, short circuits. This accounted for 40 per cent of repair time.

3. Failures of the electromechanical input and output equipment accounting for 20 per cent of the repair time.

4. Failures of d-c power supply including rectifier tubes. Ten per cent of the repair time was used for these failures.

5. Failures of ventilating equipment and protective devices which accounted for the final ten per cent of the time.

It should be noted that these times include the time to find and repair the failure. In addition it can be said that the frequency of failures falling in category 2 was reduced greatly as time passed.

Capacity. The question of capacity of a large-scale machine, that is, the maximum "size" of problem it will handle, is essentially one of programming and memory in the case of the digital devices. With a machine such as a differential analyzer or an a-c board, it is a question of the amount of equipment (for example, the number of integrators or input tables in the differential analyzer). Restricting discussion to the large-scale general-purpose digital machines where automatic programming is incorporated, as in many of the new machines, but not in the ENIAC, the question reduces substantially to memory capacity.

To illustrate, in the ENIAC interconnections of the various units for a particular problem are by external connections, and when all of the places where a connection of a given type can be made are occupied, no further connections can be made to that unit. In contrast, a machine with automatic programming is arranged so that various units performing arithmetic operations can be called into use and after completing an operation can be freed so as to be available whenever next needed. This effectively eliminates the restriction on capacity resulting from programming. However it should not be thought that the ENIAC is limited unduly in this respect. The omission of automatic programming was for the sake of simplicity, but the extensive provision for interconnections has resulted in programming not being a serious limit on capacity.

For an appreciation of the reason that memory capacity is important, some consideration should be given to modern problems. To take one particular class, consider problems in electromagnetic field theory, hydrodynamics, or elasticity, which are expressed in terms of partial differential equations. Speaking broadly, these cannot be handled by differential analyzers which are intended primarily for ordinary differential equations. It was mentioned that Kron had used the General Electric Company's a-c board to solve some problems involving partial equations in each of these fields, but although this represented a distinct advance the method is quite limited. It is possible to solve a partial differential equation by a method similar to that used to solve an ordinary differential equation on a digital machine, that is, by replacing the "infinitesimal" differentials such as dt by finite but very small differences Δt. For partial equations the process is not so simple as there is more than one independent variable. In place of a "line" of computations followed by another using the results of the first line, and so on, a grid of results must be obtained, and these must be remembered in computing other results. Estimates by persons working in the fields usually place the desirable capacity of numbers to

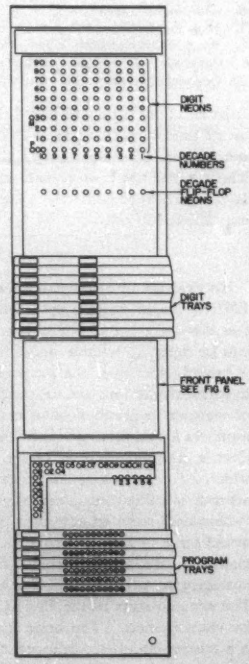


Figure 5. Front view of an accumulator

be remembered at between 1,000 and 5,000 (each number would have a certain number of digits—for example, 10 in the case of the ENIAC).

Present large-scale general-purpose digital machines could do this, but in the case of the ENIAC, for example, it would be necessary to record most of the 1,000 to 5,000 intermediate results by using the output device, and then to sort and reinsert each of these results at the right time by means of the input device. As previously mentioned, the input and output devices are slow-speed affairs, and the process would consume a great deal of time. Consequently it is reasonable to consider the capacity of the ENIAC limited in this respect. New development work in the field of the large-scale general-purpose electronic digital computers is devoted to a large extent to achieving adequate memory of the order of 1,000 to 5,000 10-digit numbers.

GENERAL DESCRIPTION OF THE ENIAC

In light of the preceding discussion the following characteristics of the ENIAC may be listed:

1. Large-scale.
2. General purpose.
3. Digital.
4. Electronic.
5. Uses 10-digit numbers.
6. Uses decimal system.
7. High speed.
8. Synchronous operation.
9. Some parallel operation possible.
10. Complete flexibility within limits of programming capacity.

In addition, it may be noted that the ENIAC consists of 40 panels erected along a U-shaped contour, plus d-c supplies for tube voltages, and so forth (Figure 2). The ENIAC has been housed in a room 30 by 50 feet. It contains approximately 18,000 vacuum tubes, and uses about 130 kw.

AN ACCUMULATOR

To describe in any detail all the sundry units in the ENIAC would require considerable space; in lieu of this the operation of one unit only—an accumulator—will be outlined, without going into circuit details.

Broadly speaking, the purpose of an accumulator is to perform additions and subtractions, to store a number, or transmit a number when called on, and to receive numbers for addition or subtraction or for storage. An electric device consisting of ten similar basic units of which all units except one were "off" or "normal" or otherwise distinguished, and one unit was "on" or in an "abnormal" state or otherwise oppositely distinguished would serve to form one column. Ten of these devices alongside one another could form the ten columns necessary to permit indication of a 10-digit number. The accumulators of the ENIAC use a "ring counter" for each column. The basic unit of the ring counter is a trigger circuit so arranged that nine of the trigger circuits are in a normal state and one in an abnormal state. Figure 3 shows a decade counter and Figure 4 a block diagram. The electric circuit includes a pulse-shaping circuit for assuring good wave form of the pulse and also includes carry-over circuits. Carry-over is required because after a counter reaches 9 the next pulse received by it should return it to 0 and add 1 in the next digit position. (Because the counter goes from 0, 1, 2, ... 9, and then back to 0, it is called a ring counter.) Carry-overs are of two types—when there is not already a 9 in the next digit position, in which instance one carry-over completes the work, and when the opposite is true. In the latter instance a further carry-over is required, and provision is made for this.

To eliminate the need for the counters to work in two directions, that is, from 0, 1, 2, ... to 9, and from 9, 8, 7, ... to 0, as would be required in ordinary addition and subtraction, the complements of negative numbers (with respect to 10^{10}) are used, and subtraction thus becomes a process in addition. However, as it is necessary to know whether a number is a simple positive number or a complement of a negative number, electrical means are provided for having an appropriate signal travel with the representative of a negative number. If P and M are used to denote respectively plus and minus quantities, then P 0,000,342,789 is the number +342,789 whereas M 9,999,452,111 represents −547,889 which is obtained by subtracting 9,999,452,111 from 10^{10}. If now the number +342,789 is in an accumulator, and the number −547,889 is sent to that accumulator to be combined with the former, the accumulator actually will receive the complement of the latter, and the operation will be

P 0,000,342,789 (in accumulator)
M 9,999,452,111 (sent to accumulator)

M 9,999,794,900 (result in accumulator)

There is a PM indicator in the accumulator which will indicate M for the result; this means that the answer is negative and that 9,999,794,900 is its complement. The true answer therefore is obtained by subtracting the latter from 10^{10} and is −205,100. Complements are obtained easily in the ENIAC, and the process of using them in place of negative numbers does not involve any great complexity.

An accumulator is not a counter, although each accumulator contains ten decade ring counters. A counter as its name implies "counts," and to get to any number such as 342,789 would go through the indications of all integers from 1 to that number. This would be a very long process. An accumulator, like a desk calculator, adds in all columns at the same time, and thus requires for its operation only the time for its counter unit (one in each digit position) to count from 0 to 9, plus time for causing carry-over, plus time for certain other processes. In the ENIAC the ring counters in each digit position are advanced by the

reception of pulses. These pulses are 2 microseconds in duration, and follow one another at 10-microsecond intervals. Nine pulses are required to carry out additions and subtractions before carry-over, and 110 microseconds are needed for carry-over and other necessities. Thus one addition or subtraction requires 200 microseconds, which is the basic "addition time," and is the interval covered by the chart in Figure 1.

Figure 5 shows the front of an accumulator, and Figure 6 gives a drawing of the front control panel appearing approximately in the center of Figure 5. As the diagram of Figure 2 shows, there are 20 accumulators in the ENIAC. The external operation of an accumulator can be explained by noting the various uses of the parts appearing in Figure 6.

In the upper left-hand corner are receptacles marked interconnecting plus I_{L1} and I_{L2}. These are for interconnection to another accumulator to enable the pair of accumulators to handle a 20-digit number. Likewise at the upper right are receptacles I_{R1} and I_{R2} used for a similar purpose.

The digit input terminals are receptacles for numbers coming to the accumulator. The lettering α, β, γ, δ, ϵ indicates five separate receptacles, any one of which can be connected to any other unit of the machine by means of the digit trunks (transmission lines) which may be plugged into at each panel. There are 11 wires in each connection, ten to carry pulses corresponding respectively to the ten digits of a 10-digit number, and the 11th to carry the P or M indication. The α, β, γ, δ, ϵ receptacles allow five incoming interconnections, so that at different times during the solution of a problem the accumulator can receive numbers from the various other units to which connections are made.

The digit output terminals are the terminals through which the number in the accumulator at a given time may be sent out (A is for add output and through it goes the number in the accumulator, S is for subtract output and through it goes the complement of the number in the accumulator). Only one output receptacle is necessary, as this may be connected to as many digit trunks for transmission to other parts of the machine as required. This does not mean that these other units will receive all outputs of the accumulator under review. The pulses arrive at all these other units, but only in those which have received a program signal to accept them will the pulses (numbers) enter.

The panel marker which has the accumulator number has the on–off switch for accumulator tube filament heaters, and shows the number of hours of operation of the tube heaters. This is desirable for maintenance. In the corresponding position on the right-hand side is the significant figure switch, which, by proper setting, results in the accumulator "clearing," that is, eliminating the number in it and indicating 0,000,000,000, except that a five is put in whatever digit position desired, if any. This is a common mathematical trick for rounding off numbers, and explains why certain simple round-off errors such as that given with an example of numerical addition earlier need not appear in the ENIAC. It does not do away however with round-off errors in general, and these are often of major importance. The selective clear switch, when in a proper position, enables the accumulator (and others with switches so set) to be cleared by a signal sent out to all from the initiating unit.

Omitting switches 1 to 4 for a moment, consider any one of the switches 5 to 12. Immediately beneath operation switch 5 for example is a repeat switch, and beneath this are shown terminals $5i$ and 5θ (i for input, θ instead of O for output because O resembles zero) all of which go with the operation switch 5. If operation switch 5 is set to α, and terminal $5i$ receives an appropriate program signal from elsewhere in the machine, then the accumulator will admit the number being sent to it on the α digit input terminal at the top of the panel, and this number will be added to whatever is then in the accumulator, of if nothing (0,000,000,000) is present the incoming number (and its sign indication P or M)

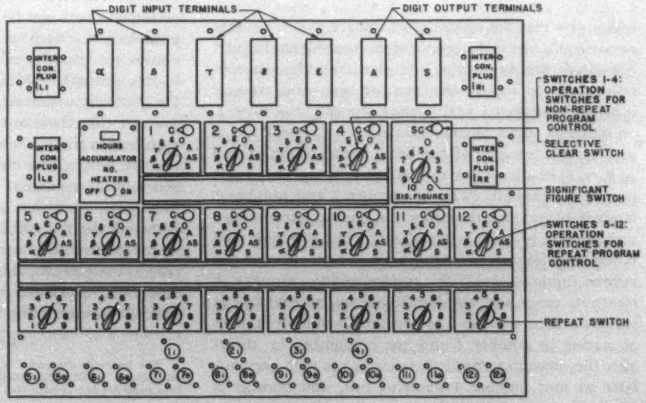

DIGIT INPUT TERMINALS
DIGIT OUTPUT TERMINALS
SWITCHES 1-4: OPERATION SWITCHES FOR NON-REPEAT PROGRAM CONTROL
SELECTIVE CLEAR SWITCH
SIGNIFICANT FIGURE SWITCH
SWITCHES 5-12: OPERATION SWITCHES FOR REPEAT PROGRAM CONTROL
REPEAT SWITCH

Figure 6. Accumulator front control panel

Terminals 1i, 2i, ... 12i—Program input terminals
Terminals 5θ, 6θ, ... 12θ—Program pulse output terminals

will be stored. If the repeat switch is set to any value such as six, the number will be received six times provided it is sent out from elsewhere in the machine at least six consecutive times. If it is sent out more than six times, the accumulator here under discussion will receive it only six times. This is a simple method of multiplying by small numbers, namely, adding the numbers together the appropriate number of times.

Consider now another switch, say operation switch 6. If it is set to A, its repeat switch to nine, and the program terminals 6θ connected to another unit of the machine (or to any of the i terminals of this accumulator) then the following will take place: The number in the machine will be sent out over the A digit output terminals (top right of figure) when an appropriate signal is received on $6i$; this will be repeated eight more times (total of nine times) because of the setting of the repeat switch; after this is done a program signal will be sent from 6θ to another unit to start operations there; if the clear correct switch is set to C the number in the accumulator will be cleared out of the accumulator in accordance with the setting of the significant figure switch but if the clear correct switch is set to 0, the number in the accumulator will be retained there.

Operation switches 1–4 are similar to those of 5 to 12, but have no associated repeat switches and no program output (θ) terminals.

This brief description of the external operation of an accumulator will tend to give an idea of the external operation of the other ENIAC units, and of the interconnections between units and the programming (except for use of the master programmer) which must be set up for a particular problem.

A common example of the use of accumulators as the only arithmetic units in a problem is that of generating the squares of all integers from 1 to 10,000 correct to 10 significant figures. Write

$$(n+1)^2 = n^2 + 2n + 1$$

which says that the square of an integer plus twice that number plus one is the square of the next higher integer. The work can be carried out thus: set the constant transmitter to supply the number one, and connect it to accumulators 1 and 2 using one of the α β, γ, δ, or ϵ digital input terminals in each. Connect the A digit output terminal of number 1 to one of the unused α, β, γ, δ, or ϵ terminals of number 2; program so that number 1 transmits twice to number 2 and number 2 receives twice, and thereafter the constant transmitter supplies one to each accumulator. The machine then proceeds as follows, assuming the numbers one and one appear initially in both accumulators: number 1 transmits twice and number 2 receives, so that one is sent twice from number 1 to number 2, resulting in three appearing in number 2 and one in number 1; thereafter the constant transmitter sends one to each accumulator so that number 1 contains two, and number 2 contains four. This is the end of the first line, and if suitable programming were arranged the result could be recorded, and the second line started.

Number 1 now sends two twice to number 2, which brings the number in the latter up to eight. The constant transmitter now adds one to each accumulator's number, so that number 1 has three and number 2 has nine. This ends the second line. This process then is continued. It is so fast that if no time is taken out for recording it can compute in six seconds the squares of all integers from 1 to 10,000 correct to ten significant figures. (Actually the process can continue beyond 10,000 to the integer whose square last falls within 10^{10}, and could go farther if accumulators were connected for 20-digit operation.)

BRIEF HISTORY

While the ENIAC exists independent of its history, it is interesting to note that it was actual pressure of computing work that led to its inception. During the war the differential analyzer of the Moore school of electrical engineering of the University of Pennsylvania was used intensively for ballistic computations; the ballistic research laboratory of the Army Ordnance Department maintained a computing center of approximately 100 trained persons (college graduates) on the Pennsylvania campus in co-operation with the University, and under separate contracts the Moore school maintained other computing groups. In addition several hundred persons (Army employees) were given intensive 3-months' training courses in mathematics, plus approximately 100 specially selected members of the Women's Army Corps. The Ordnance Department had virtually duplicate facilities at Aberdeen, Md., both as to differential analyzer and number of computers. The total computing center was probably one of the largest, if not the largest, in the world.

Despite all this it was soon evident that if the work were to continue at its then rate of growth, and if personnel could not be obtained more easily than was possible in the early years of the war, the work would outrun the capacity of the computing center. It was in this atmosphere of pressure that development of the ENIAC was undertaken, and it was because of this pressure that there are deficiencies and omissions now apparent in the machine, which nevertheless retains its position as the first electronic (high-speed) large-scale general-purpose digital machine, and which is the forerunner of numerous others now under development. Although the ENIAC is a general purpose machine, its name (electronic numerical integrator and computer) reflects the preoccupation with numerical integration of differential equations which was such an important part of war computing work.

REFERENCE

1. The Automatic Sequence Controlled Calculator, **Howard H. Aiken, Grace M. Hopper.** *ELECTRICAL ENGINEERING*, volume 65, August–September, 1946, pages 384–91; October 1946, pages 449–54; November 1946, pages 522–8.

An A-C Potentiometer

J. M. VANDERLECK
ASSOCIATE AIEE

An a-c potentiometer of the rectangular co-ordinate type has proved acceptable from both the standpoints of reliability and accuracy in circumstances where utility and ease of obtaining measurements rather than precision were the primary considerations. The potentiometer was constructed for general electrical measurements where indicating meters are unsuitable or objectionable.

THE VALUE of the d-c potentiometer in the field of d-c measurements is well known. Where conditions are such that the insertion of indicating instruments would cause too great a disturbance to a circuit to be measured, the use of a d-c potentiometer is often the most convenient means of obtaining the desired results. Where the accuracy required is beyond that available with indicating instruments, the d-c potentiometer prevails once again. In the field of a-c measurements, a suitable potentiometer would be of considerable value, and indeed, a-c potentiometers have been used to advantage from the time the electrical industry was in its infancy. Since the early days, a-c potentiometers have undergone development and improvement leading to modern instruments of several types, including precision laboratory a-c potentiometers, high-frequency a-c potentiometers, and potentiometers for geophysical prospecting.[1,2] The a-c potentiometer described in this article was not developed as a precision instrument, but as an instrument where utility and ease of obtaining measurements were the primary considerations, and where moderate accuracy would be acceptable. The accuracy available is comparable to that of high-grade portable laboratory instruments, and is sufficient for a great volume of engineering and research measurements at power line frequencies.

An a-c potentiometer with its current shunts and potential dividers is not only useful for eliminating or reducing the effects of the insertion of indicating instruments in a circuit, but, in addition, it can replace a multitude of other instruments such as voltmeters and ammeters of many ranges. The reason is the relatively constant accuracy of measurement with the a-c potentiometer over large changes in voltage and current. The accuracy of an indicating meter is usually within a fixed percentage of full scale, and thus its usefulness generally is limited to a range from one quarter of full scale to full scale, and in some instances from half scale or higher. However, within wide limits, the accuracy of the a-c potentiometer is within a fixed percentage of the reading. Thus it is possible to measure voltages or currents differing by a ratio of even 1,000 to 1 with the same accuracy.

Possibly one reason why a-c potentiometers have not been known so well in the past is because a-c bridges have provided a means of making measurements in many fields where indicating instruments were not suitable. However, the a-c potentiometer almost always excels in the measurement of voltage and current, and, in addition, the potentiometer generally has a more universal application than a bridge inasmuch as it will cover a greater variety of measurements. This is particularly advantageous in experimental work.

POLAR AND RECTANGULAR CO-ORDINATE POTENTIOMETERS

An a-c potentiometer is fundamentally a device that produces a known sinusoidal voltage of any phase or magnitude equal to the phase and magnitude of the fundamental component of an unknown voltage, and incorporates a null detector to indicate this equality. It hardly need be said that the known and unknown voltages must be of exactly the same frequency.

There are two basic methods of providing variations in phase and magnitude, resulting in two basic types of a-c potentiometers, namely, the polar co-ordinate potentiometer and the rectangular co-ordinate potentiometer. The polar type is exemplified by the Drysdale a-c potentiometer. In this type of potentiometer the output electromotive force, or the known voltage, is derived from a potential divider giving a convenient magnitude control, and the phase of the voltage across the potential divider can be varied with a phase shifter, providing the required phase control.

The rectangular co-ordinate potentiometer is based on the simple fact that an electromotive force of any phase or magnitude can be produced by two components, fixed in phase and variable in magnitude. One of the best known rectangular co-ordinate instruments is the Gall a-c potentiometer. In this type of potentiometer, two potential dividers provide two voltages in quadrature which are varied in magnitude and added vectorially to produce the required electromotive force vector. Two reversing switches are required for the output of the two potential dividers to enable a balance

J. M. Vanderleck is an engineer with Sangamo Company, Ltd., Leaside, Ontario, Canada.

to be made against an unknown electromotive force in any quadrant.

STANDARDIZATION OF A-C POTENTIOMETERS

D-c potentiometers are standardized by comparing the drop across a portion of the potential divider, consisting of dials and slide-wire, with a standard cell of known electromotive force. On first thought, it appears that a-c potentiometers could be standardized best by comparing the alternating voltage across a section of the dials and slide-wire with an "a-c standard cell," which might consist of a special a-c generator constructed with permanent magnets and driven in synchronism with the generator supplying the slide-wire current. One of the main reasons why this scheme is not practicable is because of the difficulty of keeping the a-c slide-wire current constant during the standardization. The current could be kept constant by using motor generator sets, either automatically controlled or battery-supplied, but neither method hardly can be termed either convenient or inexpensive, especially if the constancy desired is within approximately ±0.1 per cent. As a result, a-c potentiometers generally are constructed with potential dividers which are substantially noninductive, and then they can be standardized first with direct current against a standard cell in the same way as a d-c potentiometer is standardized. Then the direct current in the slide-wire is substituted by alternating current of the same value and the standardization is complete. An a-c–d-c comparator or transfer instrument must be provided to indicate the equality of the slide-wire current when it is changed from direct current to alternating current. For this purpose, a dynamometer instrument is very suitable, and both the Drysdale and Gall potentiometers use this type.

THE REQUIREMENT FOR A MODIFIED POTENTIOMETER

The polar co-ordinate potentiometer with an induction phase shifter for phase control and a single-phase potential divider for magnitude control suffers from inherent defects of the phase shifter. Because of variations in the supply voltage and frequency, the phase angle of the slide-wire current might vary even though the rotor position is fixed, and also, when the rotor is moved to adjust phase angle, the magnitude of the slide-wire current is likely to change. In addition, as a result of slot ripple in the phase shifter, it is difficult to obtain sufficiently accurate phase angle readings where accuracies within one or two minutes are desirable. The addition of a quadrature-phase slide-wire helps to overcome these defects, and, in its latest form, the Drysdale potentiometer incorporates one. With this circuit, small phase differences are balanced out by a small quadrature electromotive force from the quadrature slide-wire.

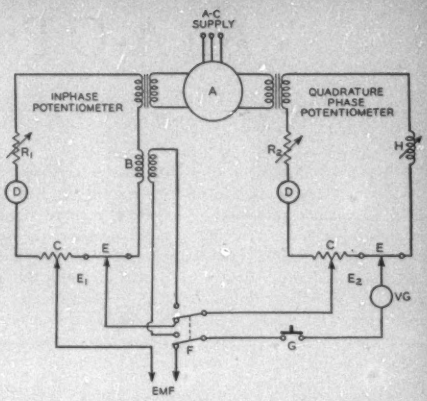


Figure 1. Fundamental circuit of modified a-c potentiometer

A—A 3-phase to 2-phase induction phase shifter
B—Mutual inductance
C—Decade
D—Milliammeter
E—Slide-wire
F—Switch S_1
G—Key
VG—Null detector
H—Reactor

By making the quadrature slide-wire or potentiometer cover the same voltage range as the "inphase" potentiometer, the result is a rectangular co-ordinate instrument which also can be used as a polar potentiometer, because the slide-wire currents are supplied from an induction phase shifter. In this way the advantages of both types of a-c potentiometers can be realized. Supplying the Gall rectangular co-ordinate a-c potentiometer with an induction phase shifter has been recommended previously,[1] and experience with the potentiometer to be described indicates that this scheme enhances the value of the instrument to a considerable extent.

The Gall a-c potentiometer is an instrument of high precision, capable of an accuracy within ±0.01 per cent. To obtain this precision, a reflecting torsion-head dynamometer milliammeter for the a-c–d-c transfer instrument is incorporated. In addition, for the highest accuracy in standardization and tests, it is almost always necessary to use a motor generator set solely for supplying the potentiometer and the apparatus under test. This motor generator set should be controlled automatically or operated from batteries or an automatically regulated d-c generator. A synchronous motor on the commercial power service reduces the d-c power requirements, but even the small fluctuations of commercial power frequency can be troublesome.

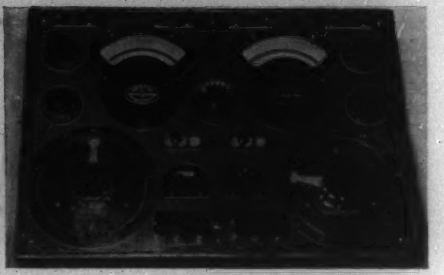


Figure 2. Main potentiometer unit

Unquestionably, of considerable value would be an a-c potentiometer which could be standardized easily and rapidly, could be operated from commercial power sources or from ordinary motor generator sets running from a commercial power supply, could be used as either a polar or rectangular co-ordinate type, and could have an accuracy comparable to high-grade portable laboratory indicating instruments. To satisfy these requirements, a potentiometer was constructed of normally available components, with the circuit substantially the same as the Gall potentiometer but with certain modifications.

THE MODIFIED A-C POTENTIOMETER

The modified instrument essentially consists of two resistance potentiometers carrying currents and producing voltages in quadrature, the currents being supplied from the 2-phase output of an induction phase shifter. The fundamental circuit diagram is shown in Figure 1.

The two resistance potentiometers are identical with regard to transfer instruments, slide-wires, decades, and current adjusting rheostats, which all are contained in one unit (Figure 2). For rapid standardization, there are two transfer instruments, one in each potentiometer. These two instruments are Weston model 370 dynamometer milliammeters, accurate within 1/4 per cent of full scale which is 55 milliamperes. By adjusting the alternating current to 50 milliamperes, both potentiometers are standardized for a range of -0.1 to $+11.1$ volts, although usually the quadrature relation must be adjusted before measurements are made. The quadrature relation is checked by the use of a mutual inductance, which carries the "inphase" potentiometer current in its primary winding and produces a secondary electromotive force in quadrature with the primary current. This electromotive force is balanced against the quadrature slide-wire by adjusting the phase of the quadrature potentiometer current with a variable reactor.

To operate the potentiometer, the procedure is quite simple. First, energize the induction phase shifter from the same a-c supply as is connected to the apparatus under test. Second, by rheostats R_1 and R_2, Figure 1, adjust the slide-wire currents to 50 milliamperes in both the "inphase" and quadrature potentiometers. Third, balance the secondary electromotive force of the mutual inductance against the electromotive force from the quadrature slide-wire. Fourth, with switch S_1 down and the two output leads connected to the unknown voltage, make a balance using the "inphase" and quadrature potentiometers simultaneously. The reading will be directly in complex volts. By the use of non-inductive shunts, currents can be measured readily, and by reading both voltage and current in a circuit, it is a simple matter to compute watts, reactive volt-amperes, power factor, and the like. If only the magnitude of a voltage or current is required, then the value can be obtained even more quickly by using the potentiometer as a polar instrument. In this instance, the electromotive force balance is made mostly on one potentiometer by using the phase shifter and one slide-wire. For convenience, final balance is made on both the "inphase" and quadrature potentiometers, and the smaller reading ignored. For example, as long as the quadrature potentiometer reading is less than seven per cent of the "inphase" potentiometer reading, the error introduced will be less than one-fourth per cent. When the a-c potentiometer is used this way, it is generally unnecessary to make the quadrature balance against the secondary electromotive force of the mutual inductance.

A variety of null detectors could be employed for a-c potentiometers, but at low frequencies one of the most useful types is the vibration galvanometer. This type has proved to be very satisfactory with the modified a-c potentiometer. It consists of a moving coil in a permanent magnet field, with the torsional vibration of the moving coil tuned to the a-c frequency being used. The amplitude of vibration provides an indication of the amount of out-of-balance voltage in the measurements.

Figure 2 shows the main potentiometer unit containing the "inphase" and "quadrature phase" potentiometers with their decade dials and slide-wire dials, dynamometer instruments, current adjusting rheostats, reversing switches, and range changing plugs. These plugs are provided to reduce the range to one-tenth the normal value of -0.1 to 11.1 volts on each of both potentiometers. On the same panel is mounted the vibration galvanometer key and shunt. The shunt protects the galvanometer from excessive currents and also reduces the sensitivity to a convenient amount before the final balance is made.

Under certain circumstances it is desirable to supply the potentiometer and apparatus under test from a single-phase supply. For this purpose, the "inphase" and quadrature potentiometers can be supplied by a

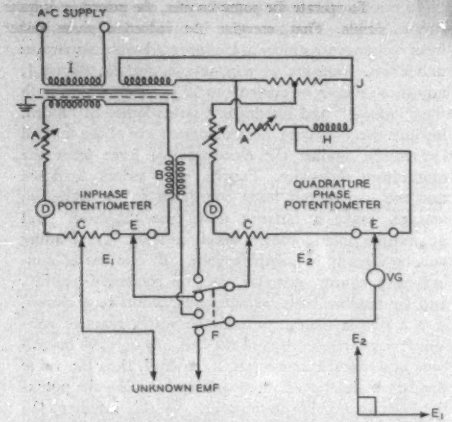


Figure 3. Modified potentiometer connected to phase splitter and single phase supply

A—Rheostats
B—Mutual inductance
C—Decade
D—Dynamometer milliammeter
E—Slide-wire
F—DPDT Switch
VG—Vibration galvanometer
H—Reactor

static phase splitter consisting of an isolating transformer, resistors, and a reactor. This is shown connected to the a-c potentiometer in Figure 3. A single-phase induction-type phase shifter using phase splitting for the stator windings and with a 2-phase output from the rotor could be applied usefully in this instance.

A complete elementary diagram showing the potentiometer wired to a switch for selecting either the induction phase shifter or the phase splitter is shown in Figure 4. The circuit diagram includes a transformer under test.

Figure 5 shows the a-c potentiometer with its auxiliaries connected for a test on the elements of an induction-type watt-hour meter. The illustration shows the vibration galvanometer, the phase splitter for supplying the potentiometer from a single-phase source, the variable reactor unit for quadrature adjustment when the potentiometer is supplied by a 3-phase source, and induction phase shifter, the mutual inductor, the main potentiometer box, a potential divider, a multiple current shunt box, auxiliary switches, and the watt-hour meter under test. This a-c potentiometer can be standardized quickly, used on commercial power service, and will give comparatively rapid results with accuracies within ±0.3 per cent to ±1 per cent, depending on the care taken and the conditions of operation. Under certain circumstances or with special care, the accuracy may be improved, but ±0.1 per cent cannot be bettered. Ratios and phase angle differences can be measured conveniently within 0.1 per cent and one minute respectively if the phase angles are small, even though the potentiometers are not standardized to a better accuracy than within 0.5 per cent. It is possible to obtain good results comparatively quickly in spite of normal supply fluctuation. Why this is so will be explained and illustrated with an account of a transformer test.

A-C POTENTIOMETER MEASUREMENTS

A-c potentiometer measurements can be made to a greater accuracy than the steadiness of the supply if the apparatus under test has linear characteristics. This is true because when the supply voltage changes, the voltage under test and the potentiometer voltage change by substantia ly the same ratio, with the result that the voltage readings on the potentiometer dials do not change. This is a factor of considerable importance in

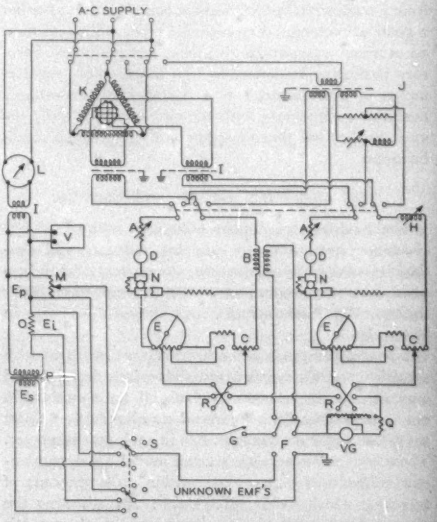


Figure 4. Elementary diagram of modified potentiometer connected with apparatus under test

A—Rheostat
B—Mutual inductance
C—Decade
D—Dynamometer milliammeter
E—Slide-wire
F—DPDT switch
G—Key
H—Reactor
I—Isolating transformers
J—Phase splitter
K—Phase shifter
L—Voltage regulator
M—Potential divider
N—Range changing plug
O—Current shunt
P—Apparatus under test
Q—Galvanometer shunt
R—Reversing switch
S—Selector switch
V—Voltmeter
VG—Vibration galvanometer

potentiometer measurements, for it is not uncommon to have plus or minus two per cent variation in the voltage of a commercial a-c supply during a measurement. The test procedure recommended for the potentiometer is simultaneously to adjust the two potentiometer currents to 50 milliamperes and the voltage across or the current through the apparatus under test to any desired value. Then the electromotive force readings obtained are the ones that exist at these values, even if the supply voltage has changed in the meantime. For example, in Figure 4, which shows a complete elementary diagram for a test on a transformer at no load, the dynamometer milliammeters both would be set to 50 milliamperes by rheostat adjustment and, at the same time, the voltage across the transformer under test would be set to 115 volts, using the voltage regulator and the voltmeter. Then the primary and secondary voltages E_p and E_s would be measured on the potentiometer. If the voltage has been set accurately, then the potentiometer reading of primary voltage E_p would be 115 volts, a noninductive potential divider being used to bring the readings within the range of the instrument, and the secondary voltage E_s might read 10.0 volts, for example. Now, if the supply voltage drops so that the voltmeter indicates 113 instead of 115 volts, the potentiometer readings are not changed, but remain at $E_p=115$ volts and $E_s=10.0$ volts. Thus, these are not true voltages any longer, but better yet, they are the voltages that would exist if the a-c supply had not changed. Of course, when apparatus is tested which has nonlinear characteristics, which is not uncommon wherever steel is used for magnetic purposes, then the foregoing relations do not hold. That is, the potentiometer reading changes when the supply voltage changes, the amount depending on the departure from linearity of the equipment. In this instance, the lack of steadiness in the supply might limit the accuracy of the measurements. However, corrections can be applied to improve the accuracy, by first obtaining an approximate characteristic curve of the apparatus with change of voltage (or current). Once the departure from linearity is known approximately, then the correction can be computed, based on the change in supply voltage when the potentiometer measurement is made. However, if a suitable voltage regulator is available, it is simpler to restore the voltage supplying all the equipment just before the final balance is made. In the transformer example cited, this refinement would be unnecessary for measuring primary or secondary voltages.

Sometimes it is necessary to read a voltage beyond the the range of the potentiometer and sufficient accuracy cannot be obtained because of the effects of the current drawn by a potential divider. This problem can be solved by the use of another piece of apparatus approximately similar to the one under test. The method can be demonstrated conveniently by reference to the aforementioned example. If E_s in Figure 4 were 100 volts and a potential divider across E_s would spoil the no-load measurements, then an approximately similar transformer would be connected in parallel on the primary side. The secondary voltage E_s' of the second transformer would be measured in the normal way with a potential divider, and the small difference voltage $E_s'-E_s$ would be read directly on the potentiometer. The desired electromotive force is the difference of the two readings, that is, $E_s=E_s'-(E_s'-E_s)$.

Sometimes a test voltage is so small that the potentiometer does not give satisfactory accuracy when operated in the normal manner. The smallest division on the slide-wire dials indicates 0.5 millivolt (for one-tenth range) and even though the division can be subdivided further to read to 0.1 millivolt, it is generally more satisfactory to read small voltages (of less than 11 millivolts) using the circuit of Figure 6. Here, a 20,000-ohm potential divider with a ratio 1,000 to 1 is connected to the two electromotive force output terminals of the a-c potentiometer. The vibration galvanometer is moved to the output circuit of the potential divider, and indicates a balance in the usual way. With this

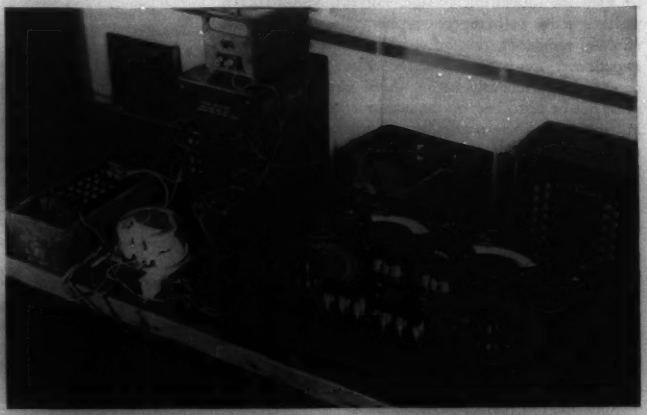


Figure 5. Complete a-c potentiometer connected with apparatus under test

Table I. Potentiometer Readings and Calculation of Results

Nominal Current (by Ammeter) Amperes	A-C Potentiometer Readings: E_2 Volts a	jb	E_1 Volts Across Shunt c	jd	R Resistance of Current Shunt Ohms	$\frac{1}{R}\sqrt{c^2+d^2}$ Amperes	Peak Ampere-Turns Per Inch $\frac{60\times\sqrt{2}\,I}{15.6}$	Watt Loss Per Pound $\frac{ac+bd}{0.089R}\times\frac{6}{7}$	Reactive Volt-Amperes Per Pound $\frac{ad-bc}{0.089R}\times\frac{6}{7}$
0.5	0.102	−j0.0054	0.384	−j0.329	1	0.506	2.75	0.393	− 0.302
1	0.252	−j0.011	0.736	−j0.682	1	1.002	5.46	1.85	− 1.57
2	0.336	+j0.081	0.295	−j0.269	0.2	2.00	10.9	3.70	− 5.48
5	0.360	+j0.222	0.773	−j0.616	0.2	4.94	26.9	5.82	−18.9

circuit, substantially the full sensitivity of the galvanometer can be realized, which means that small alternating voltages can be measured conveniently within 10 microvolts.

A current must be measured by the use of a non-inductive current shunt. In Figure 4, a reading of E_1 volts across the current shunt in series with the transformer primary is proportional to the fundamental component of the exciting current. The harmonic voltage components generally are not balanced out during a measurement but they do not interfere with a satisfactory balance of the fundamental because of the inherent properties of the tuned vibration galvanometer. The tuned galvanometer is comparatively insensitive to harmonic frequencies and the unbalanced components do not usually become objectionable unless they exceed the fundamental in value. When this happens, balances still can be made, but the accuracy of measurement suffers.

USES OF THE A-C POTENTIOMETER

The a-c potentiometer is more or less a universal instrument for low-frequency a-c measurements. It can be used for measuring voltage, current, volt-amperes, watts, reactive volt-amperes, phase angle, power factor, effective resistance, reactance, inductance, capacitance, impedance, frequency, and the like. The potentiometer is particularly useful where circuit conditions must not be disturbed by the introduction of indicating instruments. Some particular examples of the application of the a-c potentiometer are described in the following paragraphs.

CALIBRATION OF A-C INSTRUMENTS

A-c instruments such as voltmeters, ammeters, and wattmeters can be calibrated conveniently with the a-c potentiometer. However, where the accuracy of calibration must be better than within ±1/4 per cent of the reading, then a better accuracy can be achieved at the expense of losing the rapidity of standardization. To obtain accuracies within ±0.1 per cent, it is necessary to standardize the "inphase" and quadrature potentiometers against a standard cell or good d-c potentiometer. In effect, the dynamometer milliammeter transfer instruments are calibrated on direct current at one point (50 milliamperes) to within ±0.1 per cent. This requires the precautions of reversing the direct current to obtain an average reading and making occasional repeat checks in case of temporary set of the control springs.

It is worth-while noting that the a-c potentiometer is especially useful in calibrating wattmeters at low power factors. The d-c method of calibrating wattmeters ignores power factor errors entirely.

MEASURING THE RATIO AND PHASE ANGLE ERRORS OF INSTRUMENT TRANSFORMERS

With both current and potential transformers, the phase angle error and the ratio error can be measured, the accuracy not usually being limited by the potentiometer itself but by the quality of the current shunts or potential dividers required for the tests. The absolute accuracy of the potentiometer is only of secondary importance, as measurements of phase angle error and ratio can be reduced to relative measurements between the primary and secondary windings.

Figure 7 shows the principles of the current transformer test. The ratio of the shunt resistances R_1/R_2 should be the inverse ratio of the current transformer, that is, equal to I_2/I_1. Then E_1 will equal E_2, or nearly so, and the solution of the vector triangle, E_1, E_2 and ΔE gives the required information. It is apparent that

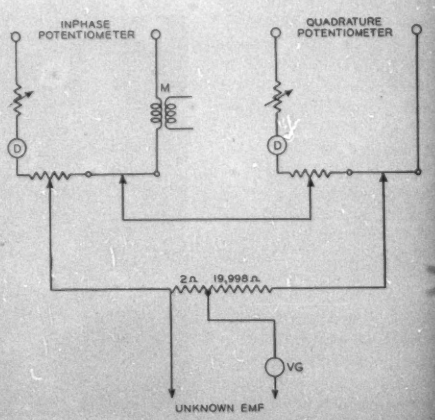


Figure 6. An accurate method of measuring voltages less than 11 millivolts

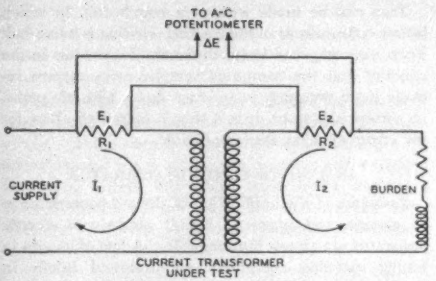


Figure 7. Determination of current transformer errors

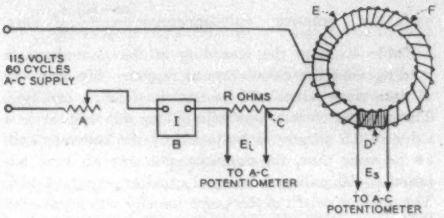


Figure 8. A steel test circuit

A—Rheostat
B—Ammeter
C—Shunt
D—Search coil, 70 turns
E—Exciting coil, 60 turns
F—Single lamination

the accuracy of the measurement depends on how well the relative magnitudes and phase angles of the two shunts, R_1 and R_2, are known. However, it is not difficult to make sufficiently noninductive shunts and to measure the resistance ratio accurately with a d-c potentiometer. Potential transformers can be tested by means of the same principle. Two potential dividers are used of the same ratio as the transformer. The method of vector triangulation enables the ratio and phase angle errors to be determined.

MEASURING MAGNETIC PROPERTIES OF STEEL

Core losses and reactive volt-amperes of magnetic materials can be measured with the a-c potentiometer. The steel either can be tested as raw material such as either a single lamination or a stack of laminations, or it can be tested after it has been built up into apparatus. It is customary to provide two windings for a measurement, one to excite the steel and the other to act as a search coil. However, when it is not convenient to do this, measurements on the exciting coil are often sufficient.

Figure 8 shows the circuit for a test of core loss and reactive volt-amperes on a single ring lamination of silicon sheet steel. The ring lamination, number 25 gauge, 3.98 inches inner diameter, and 5.93 inches outer diameter, was wound first with a search coil of 70 turns of number 38 enamelled copper wire in one layer close to the steel, and second with an exciting coil of 60 turns of number 18-gauge rubber- and cotton-covered flexible copper wire. The winding was distributed around the core.

Measurements were made of the exciting current and search coil fundamental electromotive force, with the current varied by rheostat control as shown in Figure 8. The current was forced to be substantially sinusoidal by the use of a sine wave voltage supply and a preponderance of series resistance in the circuit. If the core loss and reactive volt-ampere data were to be correlated with the peak induction, Bm, in the sample (as is usually the case) rather than with the peak ampere turns per inch, then it often can be accomplished conveniently by eliminating the large series resistance and reducing the resistance of the current shunt to as small a value as practicable in order to obtain a sinusoidal voltage and flux. In measuring watts or vars, it is essential that either the voltage or the current should be substantially sinusoidal, otherwise there is likely to be an error as a result of the power or reactive volt-amperes contained in the harmonics. Any harmonic power or reactive volt-amperes will not be detected by the a-c potentiometer.

Where the search coil of n_s turns produces a voltage of $(a+jb)$ volts and a current shunt of R ohms in series with an exciting coil of n_p turns produces a voltage of $(c+jd)$ volts, then if the current is sinusoidal, the rms amperes $=\sqrt{c^2+d^2}$, the core loss $=\dfrac{(ac+bd)}{R}\cdot\dfrac{n_p}{n_s}$ watts,

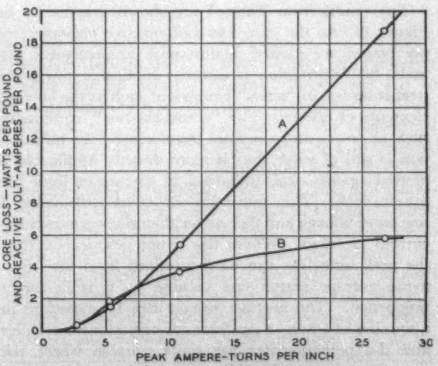


Figure 9. Test on ring sample of steel, one lamination, 60 cycles, sinusoidal current

A—Reactive volt-amperes per pound
B—Core loss

and the reactive volt-amperes $= \frac{(ad-bc)}{R} \cdot \frac{n_p}{n_s}$ vars.

Table I shows the recording of the potentiometer readings and the calculation of results. The first line of numerical values will be explained as an example. The exciting current was adjusted by the rheostat to a value of 0.5 ampere as indicated by the ammeter and, at the same time, the potentiometer currents were adjusted to 50 milliamperes and quadrature established. The selector switch of the potentiometer was set to read the search coil voltage, and readings of 0.102 and −0.0054 volt were obtained on the "inphase" and quadrature potentiometers respectively. Balancing the electromotive force from the 1-ohm resistance shunt, readings of 0.384 and −0.329 volt were obtained on the potentiometers. Thus

$$\text{current} = \frac{\sqrt{(0.384)^2+(-0.329)^2}}{1}{}^{*} = 0.506 \text{ ampere}$$

$$\text{Peak ampere turns per inch} = \frac{\text{turns of exciting coil} \times \sqrt{2} \times \text{current}}{\text{Mean length of iron path}} = \frac{(60) \times (\sqrt{2}) \times (0.506)}{15.6} = 2.75 \text{ ampere turns per inch}$$

Weight of lamination = 0.089 pound

Thus

$$\text{core loss per pound} = \frac{(0.102) \times (0.384) + (0.0054) \times (-0.329)}{1 \times 0.089} \times \frac{60}{70} = 0.393 \text{ watts per pound}$$

and

$$\text{core reactive volt-amperes per pound} = \frac{(0.102) \times (-0.329) - (-0.0054) \times (0.384)}{1 \times 0.089} \times \frac{60}{70} = -0.302 \text{ vars per pound}$$

The results from Table I are shown graphically in Figure 9. As the core loss and reactive volt-amperes per pound are plotted against peak ampere turns per inch, the information is directly applicable when the steel is for use in "series" equipment such as the current elements of meters. For "across-the-line" equipment such as power and potential transformers, the information is still of value, but is more directly applicable if plotted against peak induction in gausses or lines per square inch. The induction is calculated easily if sine wave voltage and flux rather than sine wave exciting current are used. Where this is not practicable, then the peak induction can be determined from the arithmetic average search coil voltage, as it is in direct proportion. The average voltage can be measured in a number of ways; a synchronous commutator rectifier and d-c potentiometer are quite suitable where the the voltages are small. However, it is beyond the scope of this article to discuss these methods in detail.

* The "1" in the denominator is the value of the shunt resistance.

Tests can be made without a search coil, in which instance the voltage of the exciting winding is measured. Then the computed loss includes the copper loss in the winding and the computed reactive volt-amperes include those necessary to produce fluxes with air paths. In certain situations, it is a simple matter to allow for the errors or make them negligible.

ANALYSIS OF ELECTRIC APPARATUS

Examples of the application of the a-c potentiometer to electric and magnetic circuit analysis of electric apparatus are almost innumerable. A few of its uses in testing metering equipment are discussed briefly in the following.

In watt-hour meters, the watts loss of single potential electromagnets or current electromagnets can be measured merely by obtaining readings of voltage across and current through them. Also, in the same meters, the magnitude, phase angle, and distribution of flux and change in these quantities with different loads can be determined by electromotive force measurements on search coils appropriately placed around the magnetic structures and in air gaps.

With the various types of thermal demand meters and thermal watt converters, the effect of change of temperature, voltage, load, or power factor on the performance largely can be predicted by measurements made on the small transformers which supply the heaters with current. Ratio and phase angle errors in these transformers are measured readily with the potentiometer, and their effects on the ultimate meter performance thereby can be determined. When phase shifting transformer networks are incorporated in kilovolt-ampere meters and reactive volt-ampere meters, these can be analyzed in the same way.

Induction phase shifters can be analyzed with the potentiometer and tested for relation between scale marking and phase of the output voltage.

In a-c relays, the losses can be measured, the flux paths determined, and the pull on the armature calculated from potentiometer measurements. The pull on the armature even can be found without the use of search coils inasmuch as the change in reactive volt-amperes with change in armature position definitely is related to the force on the armature.

CONCLUSIONS

An a-c potentiometer of the rectangular co-ordinate type has been constructed for general electrical measurements where indicating meters are unsuitable or objectionable. The potentiometer circuit and equipment has been designed so that measurements are affected comparatively little by fluctuations in the supply voltage and frequency, thus enabling a better precision to be obtained than the steadiness of the supply. Although the potentiometer simulates a bridge in that respect, its advantage over bridge methods is that the voltages

and currents in the circuit under test generally can be varied at will without interfering with the measuring circuit (the potentiometer).

This potentiometer has been designed for comparatively rapid measurements using commercial power service. It has been in almost continuous use since 1939 for measuring small alternating voltages and currents; for testing meters, instrument transformers, and magnetic properties of steel; and for analyzing the performance of electric apparatus. Since its construction, the potentiometer has proved to be reliable and to have maintained an accuracy within plus or minus one-half per cent for general measurements. By taking precautions with regard to the steadiness of the supply voltage and the standardization of the instrument, a better accuracy has been obtained.

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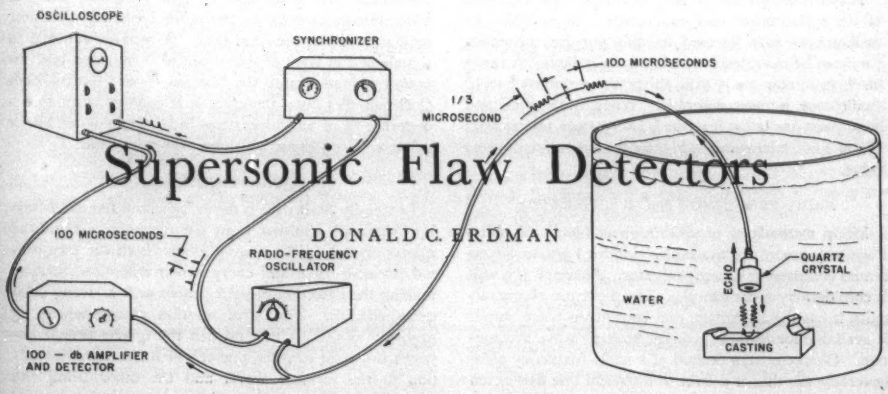

Supersonic Flaw Detectors

DONALD C. ERDMAN

Echo techniques similar to those of sonar and radar are used to locate hidden defects inside solid metal objects. They may be used in conjunction with and supplementary to X-ray testing.

HIGH - FREQUENCY sound waves traveling the length of a metal bar behave quite similarly to a transient electric signal in a long transmission line. Any abrupt changes in the distributed capacitance or inductance of the transmission line will cause a portion of the transient signal to reflect back toward the generator. The acoustic analogy is that any abrupt change in density or in Young's modulus in metal will cause a partial reflection of a pressure wave. Echoes readily are received from cracks, flakes, and holes. If working at sufficiently high frequencies, echoes can be detected from large grain boundaries.

METHOD

A small quartz crystal is used as a transducer to convert electric energy into pressure waves and conversely; thus one crystal unit acts both as a loud-speaker and a microphone. Extremely short blocks of radio-frequency power are fed to the transducer. These pulses vary in commercial equipment, but in general, depending upon the carrier frequency, may be anything from a fraction of a microsecond up to several microseconds in length. Choice of carrier frequency depends upon the type of metal being inspected, the grain size, and the distance the supersonic beam must travel. For inspection of steel castings, frequencies as low as 500 kc are common. Fifteen megacycles is desirable for inspection of aircraft forgings and extrusions. Usual repetition rate of the

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Donald C. Erdman is an electronics engineer with Triplett and Barton, Inc., Burbank, Calif.

pulses in low-frequency supersonic equipment is 60 cycles per second. Fifteen megacycle equipment, with its shorter permissible pulse widths and more rapid attenuation of the pressure wave, can use repetition rates of a 1,000 per second or higher.

The headpiece illustrates how laboratory test equipment can be assembled for the inspection of small metal objects. The quartz crystal and casting are placed under water to allow the supersonic beam to be directed into fillets and curved surfaces. When large objects are being inspected, the surfaces are usually flat enough to allow the quartz crystal to be placed directly against the part. Oil or glycerine is used to insure good acoustic coupling with the part. An ultrasonic trainer *AN/APS-T3* contains most all of the equipment needed for an experimental flaw detector.

A synchroscope can be used to combine the functions of the synchronizer and oscilloscope. More elaborate oscilloscopes may be used for this purpose, providing they can be operated in single sweep fashion. A range mark generator built into either the synchroscope or oscilloscope is most desirable. When both small and large parts are being inspected, sweep rates taking from 100 to 1,000 microseconds to cross the screen are of great value.

RADIO-FREQUENCY PULSE GENERATOR

Many methods of producing short blocks of radio-frequency power are available. Figure 1 shows the essential components of one generator. Although this unit is considerably more complex than thyratron ringer circuits, it has the advantage that continuous wave output is available for studies involving acoustic wave attenuation. Characteristics desired of a radio-frequency pulse generator are that it deliver to a coaxial line five to ten cycles of power, then wait until the next synchronizing signal arrives before sending out another wave train. The generator must present a fixed and, preferably, high impedance to the coaxial line so that returning echoes are not short-circuited by the generator. As this is not accomplished readily, the compromise is to be certain that the other ends of any coaxial lines attached to the generator are terminated properly to prevent multiple reflections of the radio-frequency pulse in the coaxial line.

A pulse one microsecond long, when converted into pressure waves, occupies one-eighth inch in metal. Thus, if the quartz crystal is in contact with the surface of a metal bar, no echoes could be detected for at least the first one-eighth inch because the transmitter is still on. This dead time is one of the more serious problems connected with inspection by echo methods. Several other factors external to the radio-frequency generator tend to lengthen the dead time. A receiver adjusted to signals of the level of microvolts will overload and remain overloaded until the damped signal from the high Q circuit dies out; therefore it is good practice to reduce the Q of all inductances in a system to as low a value as is consistent with signal-to-noise ratio.

QUARTZ CRYSTAL

Less easily dealt with is the extension of the dead time by "ringing" resulting from the mechanical Q of the quartz crystal. This ringing follows both the transmitted pressure wave and every strong reflection, thereby making the detection of weak echoes near a strong echo quite difficult. The ideal solution to mechanical Q problems would be to sandwich the quartz crystal between two solid surfaces, one of which has high attenuation to the acoustic wave, and the other being the part inspected, each having the same acoustic impedance as quartz. Much work has been done in the search for a practical liquid which will have an acoustic impedance value between quartz and steel. Mercury or mercury amalgams are quite effective where the chemical properties of mercury are not troublesome. Other workers have had some slight success coating the crystal with thin films of plastic which act to transform acoustic impedance in much the same manner as a quarter-wave line impedance transformer changes electrical impedance. When

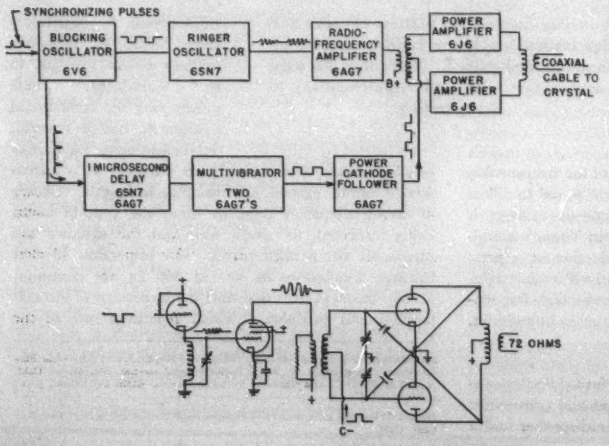


Figure 1. Radio-frequency pulse generator

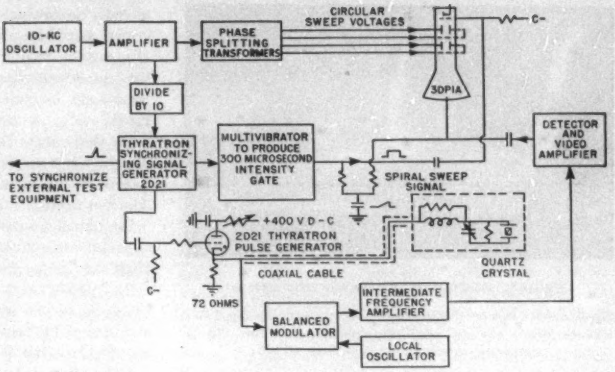


Figure 2. Simplified circuit of a portable flaw detector

chemically grown crystals such as *ADP* (ammonium dihydrogen phosphate) and *KDP* (potassium dihydrogen phosphate) can be adapted for higher frequency operation, it is likely that they will have quite an advantage over quartz, because of their low inherent mechanical *Q* and their high electric activity.

Coaxial line termination at the crystal end is quite important to the gain of the apparatus. Crystals, such as are used in the *AN/APS-T3*, have an electrical impedance of around 15,000 ohms under normal operating conditions. A π-, or L-network, usually is used near the crystal to transform the 72-ohm line impedance to 15,000 ohms. A resistance from 5,000 to 20,000 ohms across the crystal will help to damp out ringing caused by the inductance in the impedance matching network. Adjustment of the network for a maximum sensitivity to weak signals will not be the same as the adjustment for maximum discrimination between signals that occur close together. Contributing to this discrepancy are factors such as the constructive and destructive interference caused by acoustic echoes in the crystal holder.

AMPLIFIERS

An amplifier of at least 100-decibel gain is needed to bring the echo signals up to a level that can be handled by most synchroscopes. This amplifier should have a band width great enough to pass the shortest pulses used from the radio-frequency pulse generator. If operating at a carrier frequency of 15 megacycles, the band width should be approximately five megacycles. All cathode by-pass capacitors and filter capacitors should be large enough so that during the time the generator is operating no change in potential will occur across the capacitors.

The transmit-receive tube used in radar is not applicable to low power circuits as are used in flaw detection. It is, therefore, necessary that the receiver be designed to take momentary inputs of several hundred volts and yet be able to amplify a signal of a few microvolts strength immediately afterward. A superheterodyne receiver, operating with lower than normal oscillator voltage, will feed to the intermediate frequency amplifiers a signal that has quite a definite maximum value; thus overloading of these amplifiers is reduced.

An echo amplifier must be able to handle signals whose strength varies over a ratio of 100-to-1. This would indicate that some form of automatic gain control is desirable. After much experimentation to secure a system which would have rapid enough action, a promising system was developed, although it is too complicated to be commercially practical. Two amplifiers are used, one of which is used to set the gain of the other. Signals to the controlled amplifier are delayed enough so that the gain setting amplifier has time to establish the amplification of the controlled amplifier before a large signal comes along. A delay of two microseconds is adequate and can be obtained by using the delay in several hundred feet of coaxial cable.

Design of the second detector and video amplifier circuits which follow the intermediate frequency amplifier should incorporate the following features:

1. Quick recovery to strong signals.
2. Ability to pass pulses one-half microsecond long without deterioration of leading or trailing edges.
3. Freedom from ringing of the video peaking coils.
4. Sensitivity to weak signals.

These requirements are met in most radar receivers. A feature that has been incorporated in test sets where a spiral sweep is used in the indicator is to have a nonlinear resistive element across the input to the video amplifier. This helps to prevent overloading the succeeding amplifiers on strong signals. Where greatest interpretability of the wave shape of the echoes is needed, a large oscilloscope and powerful video amplifier should be used so that even the strongest signals can be shown without overloading the amplifier or without running off the screen. Fast time constant circuits as are used in radar must be used with caution in flaw detecting equipment, because of the dead time that follows long blocks of signals.

INDICATOR CHARACTERISTICS

Indicators for use with supersonic flaw detection circuits should be chosen according to the type of inspection jobs most likely to be encountered. Large oscilloscopes are desirable in fixed location equipment as the operator can be further away from the screen and still get good

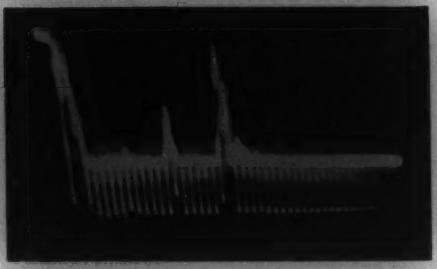


Figure 3. Oscillogram of a test bar echo pattern

Signals, reading from left to right, are transmitted signal, echo signal from a number 70 drill hole, and echo from the rear side of the bar. The 5-microsecond range marks are shown below the axis

visibility of the echo traces. In the aircraft industry and oil distilleries, portability of the testing equipment is of paramount importance, hence the need for a small oscilloscope. When limited to a small oscilloscope, a circular or spiral sweep, rather than a single horizontal trace, will allow the most echoes to be presented. An *SCR-718C* pulse-type radio altimeter contains the basic circuits needed in a circular sweep unit.

Linearity of the sweep circuit is not as important as it might seem at first, providing range marks are available. If the range marks are adjusted to occur every eight microseconds, they will correspond to one mark per inch of steel. The range mark spacing should be adjustable so that compensation may be made for the different velocities of sound in various metals and plastics.

If the operator wants an expanded view of some section of a large forging or long extrusion, a faster sweep speed can be used providing its starting time is delayed so that the interesting part of the forging is shown on the cathode-ray tube. Such delayed sweeps usually are found in synchroscopes. It is quite important that the delays be accurate and free of jitter.

COMMERCIAL DESIGN

Several carrier frequencies are necessary, with switching from one frequency to another controlled by a single dial. Figure 2 gives a block diagram of a flaw detector designed for portability. This unit uses a 3-turn spiral sweep on the cathode-ray tube. Each turn of the spiral represents one foot of steel, hence the unit is limited to forgings or extrusions less than three feet thick.

For reasons of simplicity and space saving, this unit incorporates a thyratron radio-frequency generator. Carrier frequency with this type of generator is controlled by the quartz crystal and by ringing in the impedance matching network located at the crystal. When the quartz crystal unit is changed to one of a different frequency, the tuning networks, which are integral with the crystal assembly, also are changed. Different frequency of operation requires only that the oscillator portion of the superheterodyne receiver be retuned. A 30-megacycle intermediate frequency amplifier is used. Band width is approximately four megacycles. In order that carrier frequencies of 1, 5, and 15 megacycles may be used, it is necessary to use a balanced modulator type of the first detector so that the local oscillator signal does not overload the intermediate frequency amplifier.

Regulated d-c power supplies are provided to make the apparatus relatively insensitive to line voltage changes. High voltage for the cathode-ray tube is obtained from a transformer and rectifier operated from a built-in 800-cycle power oscillator. This use of 800 cycles was necessitated by the desire to use the cathode-ray indicator unit from the *SCR-718-C* intact.

The unit may be used with an external synchroscope or other test equipment—such as a direct reading pulse position indicator or a pulse strength measuring meter. Provision has been made for using two separate crystals, as in the British system for welding inspection.

APPLICATIONS IN THE AIRCRAFT INDUSTRY

Chief interest in the new inspection tool has come about through the need for quality control on the forg-

Figure 4. Portable supersonic flaw detector used in conjunction with million-volt X-ray machine in the inspection of an aircraft forging

ings used in jet engines. Many of these parts are too thick to be X-rayed successfully, leaving no other method of internal inspection available. Supersonic inspection will detect tight cracks which are not likely to be found by X-ray methods, although X ray has quite an advantage in being able to show defects in such a manner that the operator more easily can identify the type of defect. Interpretation of defects by supersonic echo techniques is still in its infancy. It is usually true that anything that will show a strong echo is serious inside highly stressed aircraft parts. Determination of size and location of a defect is accomplished quite accurately by scanning with the quartz crystal and noting the echo position relative to the range marks. There is no well-defined limit to the thickness of a part that can be inspected by supersonic means providing the metal is homogeneous, and the proper frequency and power is used.

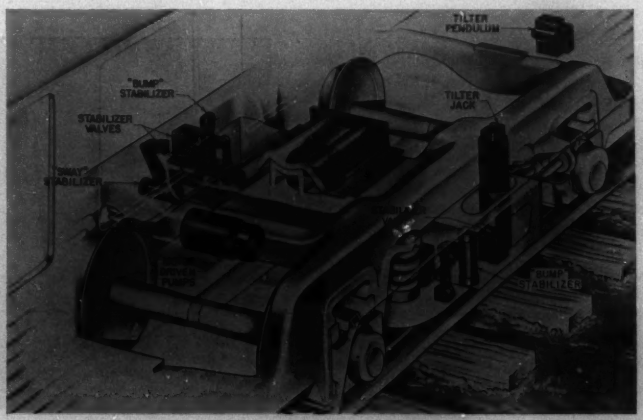
Some castings can be inspected providing they are not too porous. Magnesium castings are very transparent to 15-megacycle pressure waves. Defects common to magnesium castings, such as microshrinkage and channeling of porosity, throw strong and easily recognized echoes. Aluminum castings usually have too much gas porosity to allow good penetration of the supersonic pressure wave. If a low frequency is used, steel castings can be inspected. Forgings, extrusions, and wrought materials are penetrated most easily. Attenuation of the pressure wave in the materials is very much a function of their grain structure and hence of heat treat. A change in attenuation of two-to-one occurs in *4130* alloy (chrome molybdenum steel) between the normalized state and the heat-treated condition. Because of this sensitivity to grain size and grain boundary characteristics, most routine inspection is carried on at relatively low frequencies, such as two to five megacycles.

Sensitivity to defect is a function of the orientation of the defect to the supersonic beam direction. If the defect is normal to the beam, and if it intercepts between one and ten per cent of the beam area, it causes a detectable echo no matter how thin it is in the direction parallel to the beam. This is true because most defects are filled with gas or slag, which represents a tremendous change in Young's modulus as compared with the parent material. There is a definite relationship between the area of a defect that must be intercepted and the wave length of the supersonic pressure wave. Figure 3 shows a number 70 drill hole which easily can be shown through a foot of steel when testing at 15 megacycles. Yet, at five megacycles this defect begins to get quite noticeably more difficult to show. Long cracks usually are found no matter which orientation they have relative to the beam, because the characteristic of most cracks is either to zigzag through metal, or to turn at one end or the other. Surface cracks can be located only if the beam is pointed normal to the crack.

Quite a number of interesting characteristics are being found in metal by other than direct echo techniques. If the gain of the amplifier is turned up to where multiple echoes are visible from the back side of a billet, one occasionally will note areas on the billet where the number of these reflections changes quite radically. Preliminary test on the metal where these changes in acoustic transmission occur indicate areas of considerably different grain structure. A sudden change in grain sometimes will disperse the supersonic beam causing echoes from the back side of a part to disappear. Changing to a lower frequency usually will allow penetration through such areas.

Railroad Car Stabilizer

This stabilizer developed by Westinghouse engineers is designed to eliminate bumps and sway caused by irregularities in tracks or roads. The screw jack at the right tilts the body of the car to the proper position as it enters a curve. The two units on either side of the truck compensate for bumps or dips in the track. The sway stabilizer moves the truck wheels from side to side while holding the car body still to compensate for weaving. Floating weights and a pendulum sense irregularities in the track, anticipate the movement, and cause the various stabilizing units to operate



Electrolytic Cleaning of Rectifier Tanks

CHARLES K. ITTNER
ASSOCIATE AIEE

IN UNDERTAKING a general overhaul of a mercury arc rectifier at periodic intervals, the problem of interior cleaning of the tanks always has been a troublesome one. The tank in use usually has accumulated considerable contamination of loose material eroded from the elements of the rectifier. In addition to a dirty condition of the mercury pool, a quite hardened black slick scum may cover a large area of the tank walls. After removing all the interior parts, past practice has been either to sand-blast or wire-brush the tank walls and bottom in an effort to furnish a clean tank for the introduction of the new mercury needed for further operation.

Sand blasting and wire brushing methods are not completely efficient; neither reaches all the interior tank surfaces completely, particularly near the tank bottom where interior cooling coils may act as a barrier. In the use of sand blasting the danger exists of introducing oil or unwanted contaminants from the air line or from the sand itself, if it is used over and over again. Wire brushing, too, may leave small pieces of loose wire, or imbedded material in the tank walls. Also the operator runs the risk of mercurial poisoning unless the utmost precautions are observed.

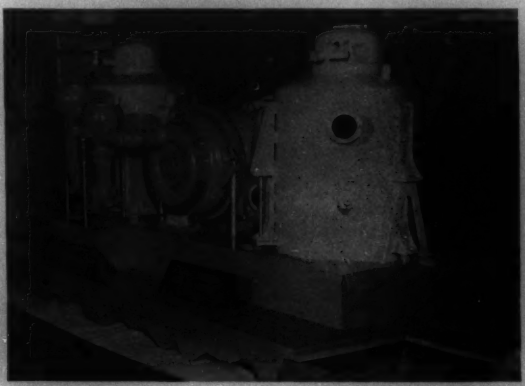
Based upon a conference paper "Electrolytic Cleaning of Rectifier Tanks," presented at the AIEE Pacific general meeting, San Diego, Calif., August 26–29, 1947.

Charles K. Ittner is an electrical engineer with the Aluminum Company of America, Vancouver, Wash.

The Vancouver plant of the Aluminum Company of America experimented with various methods of cleaning rectifier tanks. The final method tested was electrolytic cleaning using Oakite cleaning solutions, both caustic and acid, as the cleaner and electrolyte. First the tank is filled with caustic solution, rinsed, filled again, and slowly boiled with a steam coil for 30 minutes. This removes much of the heavy loose material and grease from the tank walls. Next, the tank, after being rinsed with hot distilled water, is filled with acid solution at 65 degrees centigrade. The positive terminal of a welder set is connected to the ignitron tank and the negative terminal to a suspended electrode. As the 450-ampere direct current is passed through the solution for 13 minutes, dirty material floats to the surface and hydrogen is liberated at the suspended electrode. The temperature should not exceed 72 degrees centigrade or the inhibitor is lost and the acid becomes strongly active on the tank. The walls then are washed with a high pressure jet of hot distilled water and soaked and rinsed with cold distilled water and caustic solution. A jet of dry nitrogen is used to dry the surfaces.

Earlier experiments using the tank as the cathode were not successful because of absorption of hydrogen at the wall and subsequent slow degassing. In using the tank as the anode, degassing was not critical. Perfect cleaning was secured with this process.

Mercury Turbine Model



Scale model of a new type 7,500-kw mercury turbine made by General Electric Company which is to be installed by the Public Service Company of New Hampshire at Portsmouth, N. H. Two of these mercury units are being furnished for the 40,000-kw Portsmouth station, expected to be one of the most efficient in the world. The units each consist of a mercury boiler, a 7,500-kw 1,200-rpm turbine generator, and condenser boiler. The steam output of each condenser boiler is passed through a superheater element in the combustion space of the mercury boiler. The steam flows then are combined at 600 pounds, 825 degrees Fahrenheit to feed a 25,000-kw 3,600-rpm steam turbine direct-connected to a hydrogen-cooled generator.

Electrical Essay

Magnetically Charged Electrons (or a God Has Fun)

I AM A GOD and have constructed a universe built up of positive and negative electric charges. Electrons in this universe all have the same electric charge, $-e_o$, and the charge on any body is ne_o where n is a positive or negative whole number.

I used no magnetically charged particles in this universe, so that the Maxwell's equations, which I established, are unsymmetrical. While div **D** need not be zero, div **B** must always be zero.

$$\text{Curl } \mathbf{H} = \frac{4\pi}{c}\left(i_e + \frac{1}{4\pi}\frac{\partial \mathbf{D}}{\partial t}\right)$$

where i_e is the conduction or convection electric current $ne_o v$, but,

$$\text{curl } \mathbf{E} = -\frac{4\pi}{c}\left(0 + \frac{1}{4\pi}\frac{\partial \mathbf{B}}{\partial t}\right)$$

since I created no magnetic charge whose motion would give a magnetic conduction or convection current.

I established the Lorentz force equation,

$$\mathbf{F}_e = e\left(\mathbf{E} + \frac{1}{c}[v \times \mathbf{B}]\right)$$

for the force on an electrically charged particle, but did not bother about the force on a magnetic particle,

$$\mathbf{F}_m = M\left(\mathbf{H} - \frac{1}{c}[v \times \mathbf{D}]\right)$$

as I did not use any magnetic particles in this universe.

Now that I have rested, I am going to have some fun. I am going to construct a universe with charged particles, but I am going to put both electric and magnetic charge on each particle. The electrons in this universe are going to have an electric charge of $e = -xe_0$, but they also are going to have a magnetic charge of:

$$m = -\sqrt{1-x^2}e_o$$

protons will have

$$e = +xe_o,$$

$$m = +\sqrt{1-x^2}e_o$$

and for all particles the ratio of electric charge to magnetic charge will be

$$\frac{x}{\sqrt{1-x^2}}$$

Of course, if I take $x=1$, I would have a duplicate of the universe I have just finished, so I am going to take x less than 1. Naturally now there will be net magnetic charge on bodies, and magnetic conduction and convection currents, so Maxwell's equations will be symmetrical.

It is going to be fun, watching man trying to determine the value of x.

The first thing he will do will be a Coulomb's experiment, but of course he will have to allow for the magnetism so he will find for the magnitude of the force,

$$F = \frac{e^2}{r^2} + \frac{m^2}{r^2} = \frac{(xe_o^2)}{r^2} + \frac{(\sqrt{1-x^2}e_o)}{r^2} = \frac{e_o^2}{r^2}$$

with x canceling out. Then, he will try a stream of n particles per second passing a point. At r centimeters distance, the electric current, of magnitude ne, will produce a magnetic field, of magnitude,

$$H = \frac{2ne}{r} = \frac{2nxe_o}{r}$$

and the magnetic current nm, will produce an electric field, whose component is

$$E = -\frac{2nm}{r} = -\frac{2n\sqrt{1-x^2}e_o}{r}$$

Then, he will put a particle in these fields to get the total force and he will find:

$$F = eE + mH = (xe_o)\left(-\frac{2n\sqrt{1-x^2}e_o}{r}\right) + (\sqrt{1-x^2}e_o)\left(\frac{2nxe_o}{r}\right) = 0$$

and x drops out again.

Then he really will get frantic, because then he will not know whether his electrons are all electric, $e=-e_o$, $m=0$; or all magnetic, $e=0$, $m=-e_o$; or part electric and part magnetic, $e=xe_o$, $m=-\sqrt{1-x^2}e_o$. What a joke on man! Ha, ha, ha!

• • •

Is the god right? Will man never know whether his electron is partly or wholly magnetic?

Answer to Previous Essay

The following is the solution to last month's electrical essay (*EE, Jan '48, p 58*).

The compass needle will set itself nearly perpendicular to the axis of the cylinder if, as indicated by Figure 1 of the essay, the coil is a single layer. This has been verified experimentally.

The helical system of currents flowing in the actual coil is very nearly equivalent magnetically to the superposition of *a*, a current distribution flowing exactly circumferentially around the cylinder and perpendicular to the axis, and *b*, a current distribution flowing axially along the cylinder. Here, *a* will produce nearly zero magnetic field at *A*, so that the field there will be that resulting from *b*, which is prependicular to the axis.

J. SLEPIAN (F '27)

(Associate director of research, research laboratories, Westinghouse Electric Corporation, East Pittsburgh, Pa.)

(*Continued from page 124*)

a roll has been changed, all three motors will accelerate in step. The electronic control equipment is transferred from one pair of motors to the other pair of motors, as each is operated in turn.

The fabric windup is driven at the center of the roll. As the roll diameter increases, the motor speed must be reduced, assuming the same fabric speed. Because it is desired to hold the tension of the fabric constant, the torque required from the motor shaft must increase in proportion to the roll diameter. Therefore, for a given fabric tension, constant horsepower is delivered by the motor over a four-to-one roll diameter range. The total speed range of the windup motor is 40-to-1—ten-to-one for the linear speed range and four-to-one for the change in roll diameter.

A voltage signal is obtained from the armature circuit of the windup motor as an indication of armature current. As successive layers of rubberized fabric are wound on the reel, the diameter increases and, consequently, the armature current increases. A slight increase in armature current results in a greater voltage signal to the electronic control which strengthens the field of the motor. Strengthening of the field provides the needed functions of reducing the motor speed and increasing its torque simultaneously. The accuracy of tension regulation is governed not only by the amplification in the electronic control system, but also by the amount of friction in the drive as discussed previously.

A booster generator is used in series with the armature of the windup motor to overcome the internal resistance drop of the motor. The internal drop is a function of motor load and thus the excitation of the booster voltage is adjusted automatically to suit each tension setting.

The liner letoff drive operates in a manner similar to the windup drive. The letoff motor, however, operates as a generator to provide liner tension. An increase in armature current, in this instance, provides a voltage signal which weakens the field by means of the electronic control.

TIRE BUILDING DRIVE

The application of electronic control equipment in the rubber industry is not limited to the relatively complex multimotor co-ordinated drives which just have been described. A Thy-mo-trol drive applied to a number of heavy duty tire-building machines is an example of a standard electronic drive which has been modified to meet the special application requirements of these machines. Adjustable preset high, low, and creeping speeds and adjustable high and low torques are features provided electronically which are not obtainable with conventional tire-building drives.

Figure 5 shows a heavy duty truck tire in the process of manufacture. Control of the drive in the forward and reverse directions is obtained by means of the two 2-stage foot-operated switches. Many tire-building drives are driven by constant speed a-c motors which are connected with resistance in the a-c line when the foot switch is in the first or low speed position and directly across the line on high speed. As a-c motors are inherently synchronous, however, it is necessary with a-c drives to jog the motor when applying each ply, as well as in other operations. However, with the electronic-type drive, the speed on the first position can be set to an optimum value to suit the low speed requirement for applying fabric. After each ply has been put on the drum, the drum is rotated at high speed, and the operator stitches the plies to each other by moving a pressurized roll across the fabric surface as the drum rotates. Here again, the electronic control provides a means of setting the high speed to an optimum value.

Although quick stopping is obtained on all stops by means of dynamic braking of the d-c motor, very quick stops can be obtained by operating the reverse foot switch and plugging the motor to rest, under current limit control.

This type of control also offers additional features which may be used in some applications. The small speed control potentiometer can be located in the foot switch itself so that the motor speed is continuously adjustable and is a function of the position of the foot switch. In some instances, it is desirable to have a creeping speed when the operator is working on the sidewall of the tire. In connection with the creeping speed, which can be set to run the drum at the normal pace of the operator, a very low torque also can be provided so the operator can stall the drum at will merely by pushing against it. For some types of tire-building drums, it is necessary to strip the tire from the drum using a very high motor torque. For this operation, the current, limit, and thus the motor torque, can be set for a higher than normal value.

METHOD OF CONSTRUCTION

In the last five years the development of electronic control systems has been paralleled by major improvements in construction practices. The back view of a typical Thy-mo-trol panel in current production is shown in Figure 6. All adjustments, components, and terminals are marked clearly to aid in installation and identification of circuits if maintenance is required. Screw-type terminals, in preference to solder connections, are used wherever possible to simplify maintenance and to assure tight connections, although the design is such that maintenance is actually a small problem. Tubes and components always are used conservatively to give long life. Also, special insulation and varnish treatment are used in transformers and reactors to raise the high potential breakdown voltage and to minimize susceptibility to moisture. Another example of design effort to assure proper operation under all atmospheric conditions is the use of special contact tips in relays used in all low-voltage low-current circuits.

INSTITUTE ACTIVITIES

A New Type of National Meeting— the AIEE Conference

An important innovation in AIEE meetings is being inaugurated in 1948 by several of the national technical committees of the Institute. These are to be known as AIEE conferences.

As presently conceived, the sponsoring technical committee will arrange the complete technical program, including papers, special speakers, and discussion periods, besides handling publicity including a special mailing list where desirable. The local AIEE Section in the area chosen for the conference will be asked to serve as host to the conference and handle hotel and meeting arrangements, and local publicity. In many cases, this will provide the Section with a means of augmenting its own Section meetings with interesting and timely technical matter which has been solicited by the national technical committees.

The need for such conferences was brought about in certain technical committees by their desire to attract the immediate attention of as many engineers in a certain field as possible on some of their definite projects. To achieve this end, they have conceived the idea of holding one or 2-day conference meetings on one subject or industry in a locale characteristic of that industry.

Obviously, this provides a means for AIEE members and nonmembers to concentrate on that one subject for one or two days to an extent not always feasible at a general meeting.

As a result, the technical committee sponsoring the conference reaps the benefit of this expanded discussion and interest with consequent aid to its project.

The programs for these conference meetings are planned to be technical in aspect, featuring ample opportunity for informal discussion by all attending. They will be national in their publicity and interest and both AIEE members and nonmembers will be solicited to attend and take part.

Several of these conferences are planned for 1948, covering individually, electron tubes for instrumentation and industrial use (Philadelphia, Pa., March 29–30, 1948), rubber and plastics, electronic aids to medicine, textiles, and material handling. Although some of the exact dates have not been set, programs are already in preparation, and comments or suggestions on needed topics of discussion in these fields will be welcome.

Future AIEE Meetings

AIEE Conference on Electron Tubes for Instrumentation and Industrial Use
Benjamin Franklin Hotel, Philadelphia, Pa.
March 29–30, 1948

AIEE Conference on Electrical Engineering Aspects in the Rubber and Plastics Industries
Akron, Ohio
April, 1948

Great Lakes District Meeting
Des Moines, Iowa
April 1–3, 1948
(Final date for submitting papers—January 16)

North Eastern District Meeting
New Haven, Conn.
April 28–30, 1948
(Final date for submitting papers—February 11)

Summer General Meeting
Palace of Fine Arts, Mexico City, Mexico
June 21–25, 1948
(Final date for submitting papers—February 1)

Pacific General Meeting
Spokane, Wash.
August 24–27, 1948
(Final date for submitting papers—June 10)

Middle Eastern District Meeting
Hotel Statler, Washington, D. C.
October 5–7, 1948
(Final date for submitting papers—July 21)

Midwest General Meeting
Schroeder Hotel, Milwaukee, Wis.
October 18–22, 1948
(Final date for submitting papers—August 3)

AIEE Conference on Electrical Engineering Aspects in Material Handling
Fall, 1948

AIEE Conference on Electronic Aids to Medicine
New York, N. Y.
Fall, 1948

Southern District Meeting
Birmingham, Ala.
November 3–5, 1948
(Final date for submitting papers—August 20)

Tentative Program Plans for Conference on Electron Tubes

The subcommittee on electronic instruments is rounding out program plans for the AIEE conference on electron tubes for instrumentation and industrial use to be held at the Benjamin Franklin Hotel, Philadelphia, Pa., March 29–30, 1948. The tentative program will feature technical sessions both days, including one Monday evening. This shortens the conference to two days rather than three as previously announced. Some of the principal features to be presented on the program are

1. Statement of the objectives of the conference, including an outline of the need for improved tubes, by representatives of instrument makers.
2. The results of the survey conducted by the subcommittee to determine the demand for electron tubes for instrumentation and special purposes, and their requirements.
3. An outline of the programs of electron tube development and improvement projected by special user groups in other fields.
4. A discussion of instrument tube possibilities by representatives of tube manufacturers, which will include manufacturing limitations and economic considerations.
5. Open discussion of proposed special tubes by functional types, which should bring forth many individual views of value to those who have special tube problems.

A dinner will be held Monday evening. The highlight of the after-dinner program will be a talk on a pertinent subject by a speaker prominent in the electrical field.

The committee feels sure that this conference will be of great interest to those attending and will be a significant forward step in the electronic instrument field. Details of the program will appear next month.

Great Lakes District Meeting to Be Held in Des Moines

The Great Lakes District meeting of the AIEE will be held at the Fort Des Moines Hotel in Des Moines, Iowa, on April 1–3, 1948. A number of technical sessions on subjects of power generation and distribution, control, high-frequency heating, and a symposium on nucleonic subjects are planned.

Inspection trips to the Des Moines plant of the Firestone Tire and Rubber Company, the Lake Shore Tire and Rubber Company, Solar Aircraft Company, stainless steel fabricators, and the Meredith Publishing Company are planned. An informal banquet is scheduled for Thursday evening, April 1, with a smoker set for Friday evening. Entertainment for the women will include a tea, a visit to the Meredith Publishing Company, publisher of *Better Homes and Gardens*, and a theater party.

The meeting also will be the occasion of the annual Student conference for the District with a luncheon and other sessions planned.

Hotel arrangements and reservations are being handled by J. H. O'Day, 3505 Columbia Street, Des Moines 13, Iowa.

Summer Meeting in Picturesque Mexico Offers Chance for Colorful Vacation

The choice of the city of Mexico as the site for the 1948 AIEE summer general meeting, June 21–25, provides not only an opportunity to study at first hand the technical problems and developments of a colorful and storied country, but it offers also a perfect chance for a vacation with a foreign flavor in this famed "land of contrasts." The city, which has a population of more than two million, is located on a plateau surrounded on all sides by the beautiful mountains bordering the Valley of Mexico, including the snow-capped peaks of Popocatepetl and Ixtaccihuatl. Its location in this sheltered valley and its altitude of 7,481 feet above sea level are responsible for an ideal climate, which even in the summer is an invigorating and welcome escape from the heat generally associated with that season.

The contrast between modern and Spanish-colonial architecture in Mexico City, often to be found side by side, is striking and lends the city much of its personality. The city itself covers a vast area because its subsoil does not permit the construction of buildings more than 17 or 20 stories high. To the delight of visitors, it combines the color of a foreign land with excellent up-to-date hotels and restaurants; its beautiful parks, such as Chapultepec, and picturesque countryside promise many attractive excursions.

MEETING HEADQUARTERS

Headquarters for the summer meeting will be at the Palacio de Bellas Artes (Palace of Fine Arts), where the principal technical sessions and conferences will take place. The Palace of Fine Arts is in the very heart of the city's business district. Ample parking space will be provided for automobiles of those attending the various sessions and arrangements are being made to reserve for the Institute the special parking lot in front of the Palace.

HOW TO GET TO MEXICO CITY

A brief résumé of the best means of reaching Mexico City is given in the following paragraphs. Full details on any or all of these methods of travel, as well as any other information desired, may be obtained simply by filling in the convenient coupon provided on page 54A of the advertising section of this issue and returning it to the Institute. The use of this coupon entails no obligation of any kind on the part of the sender.

By Automobile. The main port of entry for automobile traffic from the United States is at Laredo, Tex., opposite Nuevo Laredo, Tamaulipas. From Laredo, the International (also known as Pan American) Highway, which eventually will connect the Americas, affords a through route to Mexico City. This excellent paved and patrolled highway is the most widely traveled road in Mexico and is recommended as the best route for those planning to travel to the meeting by automobile. The total distance from Laredo to Mexico City is 765 miles but the highway passes through several large or medium sized cities where hotels and restaurants are available. The first of these cities, Monterrey, is one of Mexico's most important industrial centers. From this point on the trip is enhanced by the beauty and variety of scenery provided by the contrast of mountainous and subtropical zones.

The Nuevo Laredo-Mexico City trip can be made in two easily driven stages: from Nuevo Laredo to Ciudad Valles, where a comfortable night's rest and good food can be obtained; and from Ciudad Valles to Mexico City. By leaving Nuevo Laredo at about 8 a.m., Monterrey will be passed by 10 a.m. and Ciudad Valles easily can be reached by 6 p.m. Luncheon can be had either at Ciudad Victoria or Ciudad Mante. By leaving Ciudad Valles at 8 a.m. the next day and lunching at Ixmiquilpan, Mexico City can be reached at around 6 p.m.

Gasoline and oil are sold along the main traveled routes at frequent intervals, but it is best to maintain a well supplied tank and to refuel at every opportunity. The liter (litro) is the official measure and gasoline is sold in 5-liter units (about 1¼ gallons). Prices are about the same as in the United States.

Railroads. From all points located on or near the Pacific seaboard, the Southern Pacific Railroad provides easy access to Mexico, via Nogales, Ariz. The scenic attractions of this trip are impressive all the way, and the time required for the trip, from the Mexican border to the city of Mexico, is approximately four days. Visitors also may use the Mexican National Railway's Central line, entering the country at Ciudad Juarez (opposite El Paso, Tex.) with daily departures from Ciudad Juarez at 2:30 p.m. Mexican time which is Central Standard time. Total travel time is about 52 hours. This line is used to best advantage by travelers coming from the

Table I. Representative Round Trip Fares to Mexico City

Both Air and Rail Fares Are Subject to a 15 Per Cent Government Tax

From	Rail: Round Trip Fare	Rail: Pullman Lower (One Way)*	Air**
Atlanta	$117.40	$21.04	$161.20
Boston	162.73	28.74	252.60
Chicago	109.00	21.74†	186.14
Cincinnati	111.60	22.49	179.30
Dallas	64.60	14.94	94.54
Denver	97.10	21.89	163.99
Kansas City, Mo.	86.90	19.14	152.64
Los Angeles	105.70	17.64	160.20
New York	148.40	27.39	237.60
New Orleans	78.35	17.09	121.69
Philadelphia	142.31	26.94	227.90
Pittsburgh	131.90	25.14	208.60
Salt Lake City	122.95	26.39	214.94
San Francisco	129.15	20.54	194.80
Seattle	160.95	26.14	293.54
Spokane	164.26	30.24	287.14
Washington, D. C.	135.65	25.64	215.40

* Note that United States Federal tax does not apply to return Pullman tickets purchased in Mexico City; also, rates will be slightly different because they must take into account the value of the peso from Mexico City to the border.

** A very slight additional charge is made where *DC-6* service is used.

† Seat charge of $1.20 from Chicago to St. Louis, plus $20.54 for lower berth from St. Louis to Mexico City.

Table II. Representative Accommodations in Mexico City

Hotel	Accommodations	Rates Per Day for Two Persons*
Carlton	50 rooms, 50 baths	$6 (E)
Danky	25 rooms, 25 baths	4–5 (E)
De Cortes	20 rooms, 20 baths	4 up (E)
Del Prado	600 rooms and baths, 65 suites	5 up (E)
Geneve	450 rooms, 430 baths	3.50–8 (E)
Gillow	100 rooms, 100 baths	2 up (E)—per person
Guadalupe Courts	23 cottages, 23 baths	2.50
Hollywood Apartments	20 apartments, 20 baths	3–4 (E)
Isabel	75 rooms, 70 baths	3 (E), 6 (A)
L'Escargot Hotel and Cottages	50 rooms, 50 baths	3 up (E)—per person
Lincoln	100 rooms	5 up (E)
Los Angeles Courts	22 cottages, 22 baths	1.50 up (E)—per person
Majestic	100 rooms, 100 baths	5–7 up (E)
Maria Cristina	80 rooms, 50 baths	3.50 up (E)—per person
Montejo	50 rooms, 50 baths	3.25–4.75 (E)
Ontario	88 rooms, 88 baths	3 up (E)
Reforma	250 rooms, 250 baths	7–8 (E)
Regis	300 rooms, 300 baths, apartments	2.50 up (E)—per person
Ritz	150 rooms, 150 baths	3.50 up (E)—per person
Royal Courts	22 cottages, 22 baths	3–3.25
Shirley Courts	48 cottages, 48 baths	2–3.50
Toledo	35 rooms, 35 baths	4 (E)
Waldorf	125 rooms, 125 baths	5 up (E)

* Approximate equivalents in American currency at current rate of exchange of rates originally quoted in Mexican pesos.

E and A indicate European plan (without meals) or American (including meals).

vicinity of western Texas. Finally, eastern and middle western visitors going through Laredo can make connections with the daily train for Mexico City which leaves Nuevo Laredo at 1:30 a.m. and arrives 32 hours later. There is also a through train from New York to Mexico City, operated by the Missouri Pacific Lines and the Mexican National Railways, which touches many important cities in the United States and Mexico. For representative fares from key cities in the United States see Table I.

Air Lines. Pan-American World Airways, in combination with Cia. Mexicana de Aviacion, serves Mexico City from the West Coast and from Houston, Tex. Eastern Air Lines, going through Houston and connecting with Cia. Mexicana de Aviacion, has a total flying time of about ten hours between New York and Mexico City. American Airlines operates scheduled airplanes between Mexico City and New York, Chicago, and Los Angeles. The New York flight also touches Washington and Dallas; the Chicago flight, Dallas and San Antonio; and the Los Angeles flight, El Paso and Monterrey. All of these flights are run daily and some lines operate two or more runs each day. Representative fares are given in Table I.

Steamer. There is no steamer service from the East Coast to Mexico. On the Pacific Coast, at present, the tourist cruiser *Corsair* is operating between Long Beach, Calif., and the port of Acapulco in Mexico. Details on whether this method of travel will be available to those wishing to attend the summer meeting will be available at a later date.

PASSPORT AND CUSTOMS

All that is required to enter Mexico as a tourist is a so-called "Tourist Card," available at any Mexican Consulate at $2.10. Proof of United States citizenship is required to obtain the Tourist Card and should be carried at all times for identification purposes and to facilitate re-entry into the United States. No vaccination certificate is required, and personal belongings and wardrobe may be brought into the country, in reasonable quantities, free of duty. When leaving Mexico, each tourist is permitted to take into the United States $100 (United States currency) worth of Mexican goods without duty.

Although immigration and customs formalities do not offer any difficulties, the Mexican convention committee under the chairmanship of Oscar R. Enriquez is making arrangements with the Mexican authorities to provide each AIEE member with a special identification card which will facilitate further his entering the country without delay or inconvenience.

RATE OF EXCHANGE

The Mexican peso is worth approximately 26 cents at present, the official rate of exchange being $4.85 in Mexican money for one American dollar. When exchanging American currency, a small premium, generally not exceeding one-half of one cent, is charged. Individuals should arrange necessary exchange through their own banks.

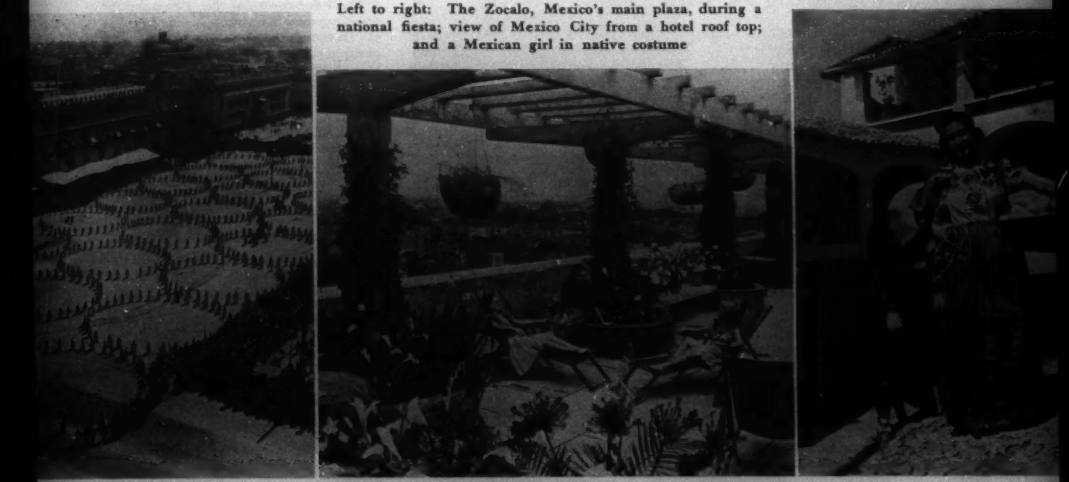
HOTELS

The hotels of Mexico City are famed for their combination of the latest in modern conveniences and design with typically Mexican color, all at reasonable rates which are dropping even more in line with the Mexican government's current campaign to beat down hotel prices. The latest of Mexico City's hotels is the luxurious state-owned Hotel del Prado which will open in March. This hotel, which boasts murals by leading Mexican artists Covarrubias and Rivera, music by Xavier Cugat, and food by imported French chefs, along with all the appointments of a Hollywood movie set, announces rates that begin at about $5 per day for a single room to about $32 a day for a suite for four persons. Among Mexico City's numerous other hotels, perhaps the Reforma, the Ritz, the Regis, the Geneve, and the Maria Cristina are best known to Americans. Rates are reasonable in all of these and are comparable to, or less than, hotel rates in the United States. Table II gives the names and rates of a number of Mexico City's better known hotels.

RESTAURANTS

A number of restaurants in Mexico City catering both to tourists and local trade have good reputations for good food, cleanliness, and reasonable prices. These include, in the vicinity of the Palace of Fine Arts, Sanborn's, Lady Baltimore, Fonda, Santa Anita, Tampico Club, Cafe de Tacuba, and Papillon. Practically all of the restaurants named serve American, European, and/or Mexican food, as well as, in some instances, sea food and other specialties.

Prices are comparable to those in the United States.



Left to right: The Zocalo, Mexico's main plaza, during a national fiesta; view of Mexico City from a hotel roof top; and a Mexican girl in native costume

Mexico City panorama

CLIMATE

Climate in Mexico is determined vertically rather than horizontally. For example, the average mean temperature in Mexico City is 68 degrees Fahrenheit, while in Cuernavaca, an hour and a half from the city, and 2,934 feet lower, it is 81 degrees Fahrenheit. Much of Mexico enjoys a delightful all-year climate, particularly in Mexico City and the plateau region. In clothing, informality is the rule. Ordinary sports clothes for both men and women (slacks, however, are not worn by women for street wear in Mexico), with dark dresses or suits for evening wear, comfortable street or sport shoes, and a spring weight top coat for evenings, are in order. While it is true that summer is Mexico's rainy season, in the plateau region the rain usually is limited to short afternoon showers, and a lightweight raincoat will afford ample protection.

The technical sessions tentatively are being planned for the late afternoon and early evening, the daily rainy period, to leave the best part of each day available for sightseeing without conflict with sessions.

REQUESTS FOR INFORMATION

All members interested in attending the summer meeting in Mexico City are urged by the special meeting committee to use the convenient "request-for-information" coupon on page 56A of this issue. This coupon, properly filled out and promptly mailed to AIEE headquarters at 33 West 39th Street, New York 18, N. Y., will bring directly to the individual complete information on travel by rail, air, or highway, as requested.

AIEE PROCEEDINGS

Order forms for AIEE *PROCEEDINGS*, and abstracts of the papers included, have been published in *ELECTRICAL ENGINEERING* as listed below. Each section of *PROCEEDINGS* contains the full, formal text of a technical paper including discussion if any, as it will appear in the annual volume of *TRANSACTIONS*. *PROCEEDINGS* are issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec '46, pp 576–8; Jan '47, pp 82–3*), and are available to AIEE Associates, Members, and Fellows.

Meetings	Abstracts	PROCEEDINGS Order Forms
Winter	Jan '47, pp 84–93; Feb. '47, pp 190–1	Feb '47, pp 33A and 34A
North Eastern District Summer General	Apr '47, pp 401–02 June '47, pp 607–14; July '47, p 708	June '47, pp 55A and 56A
Pacific General Middle Eastern District Midwest General	Aug '47, pp 840–2 Sept '47, pp 925–7 Nov '47, pp 1125–8	Dec '47, pp 55A and 56A

AIEE Board of Directors Holds Meeting in Chicago

A regular meeting of the AIEE board of directors was held at the Congress Hotel, Chicago, at 9:30 a.m., November 5, 1947, during the Midwest general meeting of the Institute.

The directors adopted a resolution in memory of Past President William E. Wickenden, who died on September 1, 1947 (*EE Jan '48, p 94*).

Announcement was made that, in accordance with the directors' interpretation of Section 35 of the constitution to mean that the two most recent past presidents shall be members of the board of directors, Past President C. A. Powel had succeeded the late Past President Wickenden on the board of directors.

MEMBERSHIP

Report was made of executive committee action on application as of September 26, 1947, as follows:

8 applicants transferred and one re-elected to the grade of Fellow; 58 applicants transferred to the grade of Member; 178 applicants elected to the grade of Associate; 378 Student members enrolled.

Recommendations adopted at meetings of the board of examiners on September 18, October 2, and October 16, 1947, were reported and approved. Upon recommendation of the examiners, the following actions were taken:

11 applicants were transferred and one was re-elected to the grade of Fellow; 75 applicants were transferred and 78 were elected to the grade of Member; 170 applicants were elected to the grade of Associate; 1,421 Student members were enrolled.

DISBURSEMENTS

Disbursements from general funds were reported by the finance committee, and approved by the directors, as follows:

August, $49,464; September, $40,918; October, $65,951.86—the October amount including payment to the Sections of their allowances for the first half of the appropriation year 1947–1948.

A budget for the appropriation year beginning October 1, 1947, was adopted as submitted by the finance committee and revised at this board meeting, amounting to $702,173.

PUBLICATIONS POLICY

During its consideration of the budget for Institute publications for the ensuing year, the directors expressed the view that the rates charged for advertising in *ELECTRICAL ENGINEERING* should be raised to equality with the advertising rates of other similar publications, approved a suggestion that the validity of the order coupon for the *PROCEEDINGS* be limited to the interval before the papers are available in the *TRANSACTIONS*, adopted the policy of issuing preprints on an essentially self-supporting basis, and referred to the publication committee for recommendation the question of changing the date of publication of the Year Book from early spring to early fall and suggestions for changes in arrangement of the membership lists.

TRAVEL EXPENSE RULES

The rules governing the allowance for travel expenses in connection with meetings of District executive committees were changed to apply to the vice-president, the District secretary, the District vice-chairman of the membership committee, the chairman of the District committee on Student activities, the chairman and the secretary of each Section in the District or their alternates, and the Sections committee representative in the District; the change to be effective for all District executive committee meetings after January 1, 1948, for which a call had not been issued.

AIEE MEETINGS

Authorization was given for the appointment of a special committee in the United States to assist in the planning and correlating of arrangements for the 1948 summer general meeting to be held in Mexico City, June 21–25.

A Middle Eastern District (number 2) meeting during the first week in October 1948 was authorized. (The meeting will be held in Washington, D. C., October 5–7, 1948).

Dates and location of the next Pacific general meeting were approved as follows: August 24–27, 1948, Spokane, Wash.

Appropriations were made to cover advances, on a refundable basis, toward the expenses of two technical committee conferences, namely, the electron tube conference to be held in Philadelphia, March 29–31, 1948, sponsored by the committee on instruments and measurements and the committee on electronics, and the conference on electrical engineering applications in the rubber and plastic industries sponsored by the general industry applications committee.

AMENDMENTS AND BYLAWS

The directors approved for submission to the membership for vote next spring, with other previously approved proposed constitutional amendments, proposed amendments to Sections 39, 40, 50, and 59 of the constitution, changing the designation of AIEE conventions to "general meetings."

Amendments to the bylaws were adopted, as follows:

Sections 6, 7, and 17 Amended. By the substitution of the words "United States, Canada, or Mexico" for "United States or Canada."

Section 30 Amended. By substitution of the word "international" for "national".

Section 65. The words "committee on management" were added directly below "committee on research" in the list of general committees.

New section, immediately following Section 84, the following information was added:

Section . . . The committee on management shall consist of a minimum of seven members. This committee shall consider problems of management insofar as they may be of importance to electrical engineers. Its scope shall include methods of organizing men, money, materials, and research activities; personnel relations; and consideration of the relations between government, industry, education, and science. The committee from time to time shall arrange general meeting programs or conferences, and shall propose articles of general interest or educational value for publication in *ELECTRICAL ENGINEERING.* The committee shall co-operate with similar committees of other organizations.

Section 85 Amended. By substitution of the word "general" for "national" in the fifth paragraph.

Section 85 Deletion. The last paragraph of this section was delected, to remove repetition.

NOMINATING COMMITTEE

The following five members of the board of directors were selected to serve on the nominating committee which will prepare an official ticket of nominees for election to Institute offices for terms beginning August 1, 1948: O. E. Buckley, E. W. Davis, W. L. Everitt, A. C. Monteith, Elgin B. Robertson. R. T. Henry and Walter C. Smith were designated alternates.

The directors confirmed the appointment by the president of D. A. Quarles to succeed the late Doctor Wickenden as a member of the Lamme Medal committee for the 3-year term ending July 31, 1950.

SECTION CHANGES

Authorization was given for the organization of the Canton Section, formerly a Subsection of the Akron Section, with an immediate territory consisting of five counties in Ohio transferred from the Akron Section, namely, Stark, Holmes, Tuscarawas, Columbiana, and Carroll.

The Illinois counties of Carroll, Henry, Mercer, Rock Island, and Whiteside were transferred from the territory of the Chicago Section to that of the Iowa Section.

Territory was assigned to the recently established Shreveport Section as follows:

6 Texas counties transferred from the North Texas Section and from District 7 to District 4

17 Louisiana parishes transferred from the New Orleans Section

The following territory was assigned to the recently organized Arkansas Section:

40 Arkansas counties transferred from the Memphis Section and from District 4 to District 7

19 Arkansas counties transferred from the Tulsa Section

9 Arkansas counties transferred from the North Texas Section

The recently established Panhandle Section was allotted the following territory:

3 Oklahoma counties transferred from the Oklahoma City Section

7 New Mexico counties transferred from the New Mexico–West Texas Section

46 Texas counties transferred from the North Texas Section

Thirteen Texas Counties were transferred from the New Mexico–West Texas Section to the North Texas Section.

MISCELLANEOUS

Upon recommendation of the AIEE committee on code of principles of professional conduct, the directors approved revised Canons of Engineering Ethics prepared by the committee on principles of engineering ethics of the Engineers' Council for Professional Development. The AIEE committee will consider the matter of harmonizing them with the AIEE Code of Principles of Professional Conduct, and report recommendations to the board of directors.

A request from the Engineers Joint Council for the appointment of a representative of the Institute to an EJC Panel on Science Research Legislation was referred to the president with power.

An invitation was accepted to participate with other affiliated and associated societies in the sponsorship of the celebration, in Washington, D. C., September 13–17, 1948, of the 100th anniversary of the founding of the American Association for the Advancement of Science.

Authorization was given for the usual travel expense allowance for a joint conference on Student activities of Districts 8 and 9 and the University of British Columbia Branch in Spokane, Wash., during the 1948 Pacific general meeting.

Other matters were discussed on which final action was not taken at this meeting.

Present at the meeting were:

President—B. D. Hull, Dallas, Tex.

Past Presidents—J. Elmer Housley, Alcoa, Tenn.; C. A. Powel, East Pittsburgh, Pa.

Vice-Presidents—J. H. Berry, Norfolk, Va.; G. W.

Left to right: F. H. Wyeth (papers and meetings), H. H. Sheppard (secretary), A. E. Welch (Raytheon Manufacturing Company), J. E. Johnson (publicity), C. S. Schifreen (treasurer), and W. R. Clark (chairman) watch demonstration of radar cooking at Philadelphia Section meeting

Bower, Haddonfield, N. J.; O. E. Buckley, New York, N. Y.; D. I. Cone, San Francisco, Calif.; R. F. Danner, Oklahoma City, Okla.; E. W. Davis, Cambridge, Mass.; I. M. Ellestad, Omaha, Nebr.; D. G. Geiger, Toronto, Ontario, Canada; T. G. LeClair, Chicago, Ill.

Directors—P. L. Alger, Schenectady, N. Y.; W. L. Everitt, Urbana, Ill.; J. F. Fairman, New York, N. Y.; J. M. Flanigen, Atlanta, Ga.; R. T. Henry, Buffalo, N. Y.; A. C. Monteith, East Pittsburgh, Pa.; J. R. North, Jackson, Mich.; D. A. Quarles, New York, N. Y.; Elgin B. Robertson, Dallas, Tex.; Walter C. Smith, Palo Alto, Calif.; E. P. Yerkes, Philadelphia, Pa.

Treasurer—W. I. Slichter, New York, N. Y.

Secretary—H. H. Henline, New York, N. Y.

Part time—B. M. Jones, chairman, publication committee; H. M. Turner, chairman, technical program committee.

Medical Electronics Subcommittee Plans Meeting in the Fall

A new electronics committee subcommittee has been formed to help co-ordinate medical and engineering development. Known as the electronic aids to medicine subcommittee, this group, under the chairmanship of Doctor W. A. Geohegan, hopes to acquaint the engineering profession with medical problems requiring engineering development, and similarly, the medical profession is to be made aware of the possibilities of electronic aids in the solution of their problems.

A 2-day conference in New York is planned for the fall of this year. The tentative program includes a wide variety of topics as is exemplified by the following subjects:

Biological requirements in amplifiers

Present practice in biological amplifier design

Biological requirements in recording devices including cathode-ray oscillograph electrocardiograph, and the electroencephalograph

Present practice in biological recorder design

Biological requirements on instruments for radioactivity measurements

Health and protection instrumentation

Biological requirements in instruments for stable isotope measurements

Present practice in biological stable isotope instrumentation

Radar Cooking Demonstrated at Philadelphia Section Meeting

"Radar in the Kitchen" was the subject of the Philadelphia Section meeting on December 8, 1947. The program was designed to be of special interest to women as well as the members and guests. The wives of some of the officers and members served coffee and doughnuts following the meeting. The whole program was admirably suited to promoting the formation of a Ladies Auxiliary for the Philadelphia Section. This movement was an outgrowth of the Montreal meeting where the women enjoyed themselves so much that it was felt the wives of the membership in general would enjoy meeting each other and participating in AIEE activities to a greater extent.

Arthur E. Welch, sales manager of the Raytheon Manufacturing Company, demonstrated electronic cooking by high-frequency electromagnetic radiations. The food was cooked dramatically in a matter of seconds whereas ordinary methods require hours. More than 30 foods were cooked in about 90 minutes during the demonstration. These included a whole lobster in 2½ minutes, a beef steak in 45 seconds, a pork chop in 45 seconds, baked apple, cranberries, fresh and frozen sandwiches, pastries, casserole dishes, fish, coffee, and popcorn. It is claimed that a higher percentage of the vitamin content of the food is retained when cooked by this method than when cooked by any other method. Those who tasted the foods agreed that the flavor and texture was superior to foods cooked in the conventional manner.

This meeting was given special publicity. Releases were sent to the three newspapers in the Philadelphia area and one newspaper, the *Daily News*, ran a feature article following the meeting. The members of the staffs of seven radio stations interested in food preparation and scientific subjects were invited. Mr. Welch was interviewed over station *WPEN* at 12:30 p.m. of the day of the meeting by Frances McGuire on her program "Talking Things Over With Frances McGuire." Invitations were extended to college faculties, especially the home economics departments.

Tidd Project Papers Available as a Special Publication

At the AIEE Midwest general meeting in Chicago a group of seven technical papers describing salient features of the 500-kv Tidd test line recently put into operation were presented. The project has excited enough interest so that a special publication including all seven papers in a single pamphlet has been made available.

The following is a list of the papers included. AIEE technical paper numbers are indicated in parentheses.

"Transmission of Electric Power at Extra-High Voltages," by Philip Sporn and A. C. Monteith. (*47-241*)

"Corona Considerations on High-Voltage Lines and Design Features of Tidd 500-Kv Test Lines," by C. F. Wagner, Anthony Wagner, E. L. Peterson, and I. W. Gross. (*47-242*)

"Insulators and Line Hardware for Tidd 500-Kv Test Line," by I. W. Gross, R. L. McCoy, and J. M. Sheadel. (*47-243*)

"Line Conductors—Tidd 500-Kv Test Lines," by E. L. Peterson, D. M. Simmons, L. F. Hickernell, and M. E. Noyes. (*47-244*)

"Transformers and Lightning Arresters—Tidd 500-Kv Test Line," by F. A. Lane, J. K. Hodnette, P. L. Bellaschi, and E. Beck. (*47-245*)

"Switchgear Equipment for Tidd High-Voltage Test Line," by F. A. Lane and B. W. Wyman. (*47-246*)

"Instrumentation and Measurement—Tidd 500-Kv Test Lines," by R. L. Tremaine and G. D. Lippert. (*47-247*)

This 50-page pamphlet is available at the AIEE Order Department, 33 West 39th Street, New York 18, N. Y., for $1 with a 50 per cent discount to AIEE members.

PERSONAL • • • •

Joseph Slepian (A '17, F '27) associate director of research, research laboratories, Westinghouse Electric Corporation, East Pittsburgh, Pa., and 1942 winner of the Lamme Medal, has been awarded the Edison Medal for 1947. The Edison Medal, one of the nation's top engineering honors for meritorious achievement in electrical science, was awarded to Doctor Slepian "for his practical and theoretical contributions to power systems through circuit analysis, arc control, and current interruption." He received the medal on January 28, 1948, during the winter meeting of the AIEE in Pittsburgh, Pa. Doctor Slepian was born in Boston, Mass., on February 11, 1891. He attended Harvard University, from which he received a bachelor of arts degree in 1911, a master of arts degree in 1912, and a doctor of philosophy degree in mathematics in 1913. He then spent the year 1913–14 abroad studying as a Sheldon fellow at the University of Göttingen in Germany and at the Sorbonne in Paris, France. Doctor Slepian accepted a post as mathematics instructor at Cornell University, Ithaca, N. Y., upon his return from Europe, but several months later resigned to take an apprentice's job at the East Pittsburgh (Pa.) Works of the Westinghouse corporation. He became associated with the research laboratories of the company in 1917. His skill as a mathematical physicist led him to be consulted more and more in varied fields until in 1917 he gave up his duties as an assistant to devote more time to consultation. Doctor Slepian then was made engineer in charge of the general section of the research department in 1922 and research consulting engineer in 1926. He was appointed to the position which he now holds in 1938. Doctor Slepian developed the Ignitron and did outstanding pioneer work in the design of circuit breakers and lightning arresters for the protection of power systems. He is known internationally for his development of high-speed methods of extinguishing arcs in electric power systems. Doctor Slepian has specialized particularly in the field of discharge phenomena in gasses and has rendered

Joseph Slepian

J. R. Pierce

J. M. Wallace

E. M. Williams

valuable assistance in many other branches of electrical engineering. He has written valuable scientific and engineering papers which have been published in various technical magazines and he has many inventions to his credit. Despite the fact that his formal education in higher mathematics included nothing about electrical engineering, Doctor Slepian is considered one of the world's outstanding electrical engineers. During the war he carried on important work for the atomic bomb project, served as a consultant to the Office of Scientific Research and Development, and as a "dollar-a-year man" with the War Production Board. In 1932 he was awarded the John Scott Medal and in the following year he won the AIEE national prize for the best paper in theory and research. He was elected to the National Academy of Science in 1941. Doctor Slepian is a member of the American Mathematical Society, the American Physical Society, the American Electrochemical Society, the American Association for the Advancement of Science, and of Phi Beta Kappa. He was chairman of the AIEE basic science committee in 1933–34, and has served on the AIEE basic science committee, 1924–34, and 1938–42; electric welding committee, 1930–36; technical program committee, 1933–34; research committee, 1940–42; and electronics committee, 1942–44.

J. R. Pierce (A '39) electron dynamics research group head, Bell Telephone Laboratories, Inc., New York, N. Y., has been named the Eta Kappa Nu Recognition Award recipient for 1942. The presentation of this award, normally given annually to the most outstanding young electrical engineer, had been postponed due to the war. Doctor Pierce was born in Des Moines, Iowa, on March 27, 1910. He entered the California Institute of Technology from which he received a bachelor of science degree in electrical engineering in 1933 and a degree of doctor of philosophy in 1936. After graduation Doctor Pierce entered the employ of the Bell Telephone Laboratories where he was engaged in research work. In collaboration with another Bell system engineer he developed the "Pierce-Shepherd tube," one of the most widely used types of reflux oscillator tubes. During the war Doctor Pierce was a member of a group sent to England under the auspices of the United States Navy to study British tube work. While there he realized the possibilities of traveling wave tubes which he had seen being developed in England and on his return to the United States he developed the traveling wave amplifier tube. For this accomplishment Doctor Pierce later received the Morris Liebmann Award of the Institute of Radio Engineers. He has demonstrated his ability in both analysis and invention in other fields too, and has contributed important original ideas in telegraphic code work, communication switching devices, radio antennas, and wave filters. He has written articles for both popular and technical engineering magazines and he writes for the magazine *Astounding Science Fiction* under the pen name of J. J. Coupling. Doctor Pierce is a member of Tau Beta Pi, the Institute of Radio Engineers, and of the American Physical Society.

J. M. Wallace (A '41) head of switch and fuse section, switchgear division, Westinghouse Electric Corporation, Pittsburgh, Pa., has been named the recipient of the 1945 Eta Kappa Nu Recognition Award. Born on February 25, 1914, in Pittsburgh, Pa., Mr. Wallace was graduated from the University of Pittsburgh in 1935 after taking what would correspond to an electrical engineering major now. He was employed in 1935 by the Westinghouse Electric Corporation as an apprentice and in 1937 was transferred to the switchgear division as a designer of high power fuses for distribution service. In 1943 he was promoted to the position which he now holds. Mr. Wallace is a past president of the Westinghouse Engineers' Society and is a member of the National Electrical Manufacturers Association.

E. M. Williams (A '40, M '47) electrical engineering department, Carnegie Institute of Technology, Pittsburgh, Pa., has been named the recipient of the Eta Kappa Nu Recognition Award for 1946. Born on February 2, 1915, in New Haven, Conn., Doctor Williams was graduated from Yale University in 1936 with high honors and a bachelor of engineering degree after he had earned the New Haven County Yale Alumni Scholarship for two years, the Goetchius Scholarship and the Richardson Scholarship, each for one year, a prize for excellence in economics, and the E. O. Lanplier prize for proficiency in research. He received a doctor of philosophy degree in 1939 from Yale University after three years of study during which he won the Yale Engineering Association Scholarship three times and was a Charles A. Coffin Fellow in 1938–39. Doctor Williams was an instructor in electrical engineering at Pennsylvania State College from 1939 to 1942. He served as a branch engineer, in the development branch special projects laboratory, Wright Field, Dayton, Ohio, from 1942 to 1945, and his wartime work on radar, development of radio counter measures, radio control for guided missiles, and infrared systems was so commendable that he was awarded a Presidential Certificate of Merit. In 1945 Doctor Williams accepted a position as associate professor of electrical engineering at the Carnegie Institute of Technology. He has written and presented many technical papers and talks at meetings of various societies. One of his papers received honorable mention in the national AIEE Student paper competition in 1936 and another won the award for the best graduate paper in the AIEE Northeastern District contest of 1937. Doctor Williams is a member of Sigma XI, Tau Beta Pi, the American Association of Uni-

W. J. Fleming

S. B. Cohen

R. R. Hough

versity Professors, the American Society for Engineering Education, Eta Kappa Nu, and of the Institute of Radio Engineers. He is the AIEE Student Branch counselor at the Carnegie Institute of Technology for 1947–48.

R. R. Hough (A '41) member of the technical staff, Bell Telephone Laboratories, Inc., Whippany, N. J., has been named the recipient of the Eta Kappa Nu recognition Award for 1947. Mr. Hough was born in Trenton, N. J., on December 13, 1917. He attended Princeton University and received a bachelor of science degree in engineering in 1939 from that institution. He served as a part-time instructor in electrical engineering at Princeton University, (N. J.) while working for an electrical engineering degree which he received in 1940. Mr. Hough became associated with the technical staff of the Bell Telephone Laboratories, Inc., New York, N. Y., in 1940. He is a member of the Institute of Radio Engineers.

G. D. McCann, Jr. (A '38, M '44) professor of electrical engineering, California Institute of Technology, Pasadena, Calif., has been named one of the 1942 recipients of the Eta Kappa Nu Honorable Mention Award. Born on January 12, 1912, in California, Doctor McCann was graduated from the California Institute of Technology in 1934 with a bachelor of arts degree in electrical engineering. He received a master of science degree in 1935 and a doctor of philosophy degree in 1939 from the same institution, having held teaching fellowships there from 1934 to 1938. He was employed by the Westinghouse Electric and Manufacturing Company (now the Westinghouse Electric Corporation) in 1938 as a central station engineer and was promoted to the position of transmission engineer in 1941. During the war Doctor McCann served as a consultant to the Army Ordnance safety department and to munitions manufacturers. He was appointed associate professor of electrical engineering at the California Institute of Technology in 1946. He was the recipient of the AIEE national best paper prize in theory and research in 1942 and in 1945. Doctor McCann is a member of Sigma Xi and is serving on the AIEE basic sciences committee for 1947–48.

D. B. Smith (A '35) vice-president in charge of engineering, Philco Corporation, Philadelphia, Pa., has been named a recipient of the Eta Kappa Nu Honorable Mention Award for 1942. Born on December 3, 1911, in Newton, N. J., he was graduated from the Massachusetts Institute of Technology with a bachelor of science degree in 1933 and a master of science degree in 1934. Since graduation Mr. Smith has been associated continuously with the Philco Corporation and its predecessors, the Philco Storage Battery Company and the Philco Radio and Television Corporation. He began his career with the Philco Corporation as a patent engineer, and subsequently was promoted to assistant head of the patent department, engineer in charge of special studies, technical consultant to the vice-president in charge of engineering, and director of research. He was appointed to the position which he now holds in 1945 and he is also a director of the corporation and a member of its executive committee. Mr. Smith was a member of the original television committee of the Radio Manufacturers Association and in 1945 he was chairman of the television systems committee of that organization. He is a director of the Institute of Radio Engineers, and a member of the American Association for the Advancement of Science, the Franklin Institute, and of Tau Beta Pi. He is serving on the AIEE communications committee for 1947–48.

J. W. McRae (A '37) Bell Telephone Laboratories, Inc., New York, N. Y., has been named one of the recipients of the Eta Kappa Nu Honorable Mention Award for 1943. Born on October 25, 1910, in Vancouver, British Columbia, Canada, he was graduated from the University of British Columbia in 1933. Doctor McRae became a graduate assistant at the California Institute of Technology and obtained a master of science degree in electrical engineering in 1934 and a doctor of philosophy degree in engineering in 1937. He became associated with the Bell Telephone Laboratories in 1937, but left that organization during the war to accept a commission in the Signal Corps. His work was rewarded in 1946 when he was awarded the Legion of Merit. Doctor McRae returned to the Bell Laboratories in 1946 and subsequently was promoted to director of electronic and television research. He is a member of the Institute of Radio Engineers, the Summit, N. J., Association of Scientists, and of Sigma Xi.

A. G. Kandoian (A '40, M '46) division head, Federal Telecommunication Laboratories, New York, N. Y., has been named a recipient of the Eta Kappa Nu Honorable Mention Award for 1943. Born on November 28, 1911, in Van, Armenia, Mr. Kandoian came to the United States with his family in 1922. He was graduated cum laude in 1934 from the undergraduate engineering school of Harvard University, and obtained a master's degree from the Harvard graduate school of engineering in 1935. In June of that year Mr. Kandoian was employed by the International Telephone and Telegraph Company for whom he since has worked continuously. During the war he conducted a series of technical lectures for training of advanced service as well as nonservice personnel in the theory and practice of radio propagation, radiation, and design of antennas. He is a member of the Institute of Radio Engineers and of Tau Beta Pi.

D. W. Pugsley (A '36) television section head, General Electric Company, Bridgeport, Conn., has been named one of the recipients of the Eta Kappa Nu Honorable Mention Award for 1944. Born on December 4, 1912, in Salt Lake City, Utah, Mr. Pugsley was graduated from the University of Utah in 1935 with a bachelor of science degree in electrical engineering. He was employed in the receiver division of the electronics department of the General Electric Company in 1935 and by 1939 had been promoted to the position of radio receiver development engineer. In 1939 he was also television engineer, responsible for the design, construction, and installation of the complete television equipment in the General Electric building at the New York World's Fair. During the war Mr. Pugsley was responsible for the design and development of secret electronic equipment for the Armed Forces. He is serving on the Radio Manufacturers' Association and the Institute of Radio Engineers television committees, and he is a member of the Institute of Radio Engineers and of Tau Beta Pi.

W. A. Depp (A '38) technical staff, Bell Telephone Laboratories, Inc., New York, N. Y., has been named one of the recipients of the Eta Kappa Nu Honorable Mention Award for 1945. Born on December 22, 1914, in Summer Shade, Ky., Mr. Depp was graduated with a bachelor of science degree in electrical engineering from the University of Illinois in 1936. Because of his outstanding academic record he was awarded a Tau Beta Pi fellowship for the year 1936–37 and he remained at the University of Illinois from which he received a master of science degree in 1937. Shortly after receiving that degree he was employed by the Bell Laboratories where he now is interested primarily in the development of new types of gas-filled electron tubes. Mr. Depp was in charge of the "spark gap" tube development in the laboratories during the war. He is a member of the Institute of Radio Engineers, the Association of New York Scientists, Eta Kappa Nu, Tau Beta Pi, and Sigma Xi. In 1946, in recognition of his "noteworthy achievement as an original investigator," Mr. Depp was awarded an active membership in Sigma Xi as an alumni member by the University of Illinois chapter.

D. L. Waidelich (A '39, M '44) professor of electrical engineering, University of Missouri, Columbia, has been named one of the recipients of the Eta Kappa Nu Honorable Mention Award for 1946. Born in Allentown, Pa., on May 3, 1915, Doctor Waidelich was graduated from Lehigh University with a bachelor of science degree in electrical engineering in 1936. In 1938, following two years as a graduate teaching assistant at Lehigh University, he received a master of science degree and in 1946 he received a doctor of philosophy degree in electrical engineering. After he received his masters degree in 1938 Doctor Waidelich accepted a position as an instructor in the electrical engineering department of the University of Missouri. He subsequently was promoted to an assist-

ant professor, an associate professor, and then to a professor, the position which he now holds. He was a section head on research and development work on electronic devices associated with subsurface ordnance weapons and equipment at the Naval Ordnance Laboratory during the war, and received a Naval Ordnance Development Award for that work. Doctor Waidelich is a member of Eta Kappa Nu, Tau Beta Pi, Sigma Xi, the Institute of Radio Engineers, and of the American Society for Engineering Education. He served as an AIEE Student Branch counselor from 1941 to 1944.

A. C. Hall (M '44) director of the dynamic analysis and control laboratory, Massachusetts Institute of Technology, Cambridge, has been named a recipient of the Eta Kappa Nu Honorable Mention Award for 1946. Born in Port Arthur, Tex., on June 27, 1914, he was graduated with an electrical engineering degree, from the Agricultural and Mechanical College of Texas in 1936. During 1936–37 Doctor Hall was a full-time graduate student at the Massachusetts Institute of Technology and in 1937–38 he served as a laboratory instructor at that institution while carrying a part-time program of study. He received a master of science degree in 1938 after which he served another year as a laboratory instructor. He then was made an instructor and assistant in charge of the measurements laboratory and from 1940 to 1943 he was an instructor and research engineer in developing automatic control equipment for defense applications. He was awarded a doctor of science degree in 1943, and in that same year was made an assistant professor at the Massachusetts Institute of Technology. Doctor Hall became project engineer in the servomechanisms laboratory and acting director for a period in the absence of the director. He later received a Naval Ordnance Development Award for his wartime work on guided missiles. Doctor Hall was appointed to his present position in 1946. He is a member of the Institute of Radio Engineers, the American Society of Mechanical Engineers, the Instrument Society of America, and of Sigma Xi.

Marvin Camras (A '41, M '47) research physicist, Armour Research Foundation, Chicago, Ill., has been named one of the recipients of the Eta Kappa Nu Honorable Mention Award for 1947. Born on January 1, 1916, in Chicago, Ill., he received a bachelor of science degree in 1940, and a master of science degree in electrical engineering in 1942 from the Illinois Institute of Technology (in 1940 known as the Armour Institute of Technology). Since 1940 Mr. Camras has been employed as a research physicist by the Armour Foundation where he has been engaged in research, design, and construction of electronic equipment and magnetic recorders. He is a member of the Acoustical Society of America, the Institute of Radio Engineers, and of the Society of Motion Picture Engineers.

G. G. Post (A '11, F '33) vice-president in charge of power, Wisconsin Electric Power Company, Milwaukee, retired recently after 41 years of service with that company. Born on September 15, 1881, at Madison, Wis., he was graduated in 1904 from the University of Wisconsin with a bachelor of science degree in electrical engineering. Mr. Post served as an assistant instructor and later as an instructor of electrical engineering at the University of Wisconsin, Madison, from 1904 to 1906 when he accepted a position as an assistant electrical engineer in the lighting department of the Milwaukee Electric Railway and Light Company (now the Wisconsin Electric Power Company). He then was promoted successively to the positions of superintendent of electrical testing; electrical engineer, lighting department; and chief engineer, electrical division. In 1929 Mr. Post was appointed to the position which he held at the time of his retirement. He is a member of the Engineers' Society of America, and of the National Electric Light Association. Mr. Post has served on various technical committees, including the AIEE power generation committee from 1932 to 1939, protective devices committee from 1934 to 1936, Edison Medal committee for the year 1935–36, and the commission of Washington Award from 1936 to 1939.

R. C. Muir (A '08, F '36) general manager, apparatus department, General Electric Company, Schenectady, N. Y., has retired after more than 42 years service with that organization. Born on December 30, 1881, at Arcadia, Wis., he was graduated from the University of Wisconsin in 1905 with a bachelor of science degree in electrical engineering. In 1905 Mr. Muir entered the test course of the General Electric Company and during the second year of that course served as assistant to the head of turbine testing. In 1907 he was transferred to the turbine engineering department and a year later he joined the power and mining engineering department, now the industrial divisions. In 1919 Mr. Muir was appointed chief commercial engineer of the newly organized International General Electric Company, but in 1922 he returned to the Schenectady, N. Y., General Electric offices as assistant engineer of the industrial engineering department. In 1930 he was made general assistant to the vice-president in charge of engineering and three years later was appointed manager of the engineering department. Mr. Muir was promoted to vice-president in charge of engineering the following year, and was made a member of the president's staff in 1941. He relinquished these special duties in 1944 to take over the position which he held at the time of his retirement. Mr. Muir was awarded the honorary degree of doctor of engineering by the University of Wisconsin, and in 1942 a similar honor was conferred on him by Manhattan College. He is a member of the American Society of Mechanical Engineers, the Institute of Aeronautical Sciences, the Army Ordnance Association, the University Club of New York, and of the Engineering Club of New York. Mr. Muir served on the AIEE planning and co-ordination committee from 1939 to 1942, a special AIEE committee on posthumous honors from 1939 to 1941, a special AIEE committee on radio talks on electrical engineering subjects from 1939 to 1941, the AIEE institute policy committee from 1940 to 1942, and on the AIEE members-for-life fund committee from 1944 to 1948.

A. K. Morehouse (A '20, M '31) supervisor of personnel relations, The Pacific Telephone and Telegraph Company, Portland, Oreg., has retired after 45 years of service with the Bell system. Born on January 14, 1883, at Olney, Ill., he received his technical knowledge through one year of postgraduate study in high school and a four months transmission engineering course. Mr. Morehouse was employed in 1902 by the Western Electric Company, Chicago, Ill., and Denver, Colo. He was made central office maintenance and wire chief for the Bell Telephone Company of Missouri, St. Louis, in 1905, and in 1906 was transferred in the same capacity to the Colorado Telephone Company, Denver and Longmont.

J. F. Getz

Gloria Brooks

R. E. Murphy

He was employed by the Pacific Telephone and Telegraph Company, Sacramento, Calif., in central office maintenance in 1908, and in 1909 was appointed central office inspector for the San Francisco, Calif., office. Mr. Morehouse was wire chief for the Napa, Calif., branch of the Bell system in 1910 but transferred to the Portland, Oreg., office later in that year as central office maintenance, wire chief, central office installation, foreman and supervising foreman. He was promoted to division equipment foreman for the Spokane, Wash., office in 1919, but in 1920 returned to the Portland branch as engineer of transmission problems. He subsequently served as division transmission engineer, general toll supervisor, and toll service supervisor prior to his promotion to the position which he held at the time of his retirement.

C. A. Wolfrom (A '10) manager, Salt Lake Division, Utah Power and Light Company, Salt Lake City has retired. Born on December 22, 1881, at Bellevue, Ohio, he attended the Telluride Institute and the University of Michigan. He was employed by the Telluride Power Company, Grace, Idaho, as a station operator in 1902, and subsequently rose to become superintendent before leaving the company to accept a position as assistant to the general superintendent, Utah Power and Light Company. Mr. Wolfrom has been the manager of the Salt Lake Division since 1927. He served as chairman of the Utah Section of the AIEE for the year 1937–38.

L. C. F. Horle (A '20, F '35) consulting engineer, New York, N. Y., has been named the 1948 winner of the Medal of Honor awarded annually by the Institute of Radio Engineers. This honor has been awarded to Mr. Horle for "his contributions to the radio industry in standardization work, both in peace and war, particularly in the field of electron tubes, and for his guidance of a multiplicity of technical committees into effective action." The medal is the institute's highest award and is presented in recognition of distinguished service rendered through substantial and important advancement in the science and art of radio communication. The recipient of the medal is named by the board of directors of the institute upon recommendation by the awards committee. Mr. Horle was born on May 27, 1892, in Newark, N. J. He was graduated from Stevens Institute of Technology in 1914 as a mechanical engineer and, after teaching at that institute for two years, held successive positions in the field of radio. He has been a practicing consultant, specializing in industrial standardization in the communications field, since 1929. Mr. Horle is chief engineer of the Radio Manufacturers Association, in charge of the RMA data bureau. He is a fellow and past president of the Institute of Radio Engineers and he served on the AIEE electronics committee from 1945 to 1947.

W. H. Huggins (A '43) chief, receiver research branch, communication laboratories, Army Air Forces, Cambridge Field Station, Cambridge, Mass., has been awarded the Browder J. Thompson Memorial Prize, given by the Institute of Radio Engineers, for his paper on "Broadband Noncontacting Short Circuits for Coaxial Lines." This memorial prize comprises the income from a fund established by voluntary contributions to preserve the memory of Browder J. Thompson, a director of the IRE when he was killed in action during World War II. Mr. Huggins was born on January 11, 1919, in Rupert, Idaho. He attended Oregon State College, from which he received a bachelor of science degree in electrical engineering in 1941 and a master of science engineering degree in 1942. Mr. Huggins is a member of the Institute of Radio Engineers and of Sigma Xi. He served as AIEE Student Branch counselor at Oregon State College in 1943–44.

T. S. Knight (A '05) commercial vice-president, General Electric Company, Boston, Mass., has retired after 44 years of service with that company. Born on February 4, 1882, at Somerville, Mass., he was graduated from Tufts College in 1903 with a bachelor of science degree in electrical engineering. In that same year he was employed by the General Electric Company, Schenectady, N. Y., as a student engineer on the test course. In 1907 Mr. Knight was transferred to the Boston, Mass., office, where he became the organization's first product specialist. During the first World War he was on the War Industries Board in charge of the electrical division, and shortly after his return to Boston he was named assistant manager for the New England district of the General Electric Company. He was appointed district manager in 1926. The board of directors of that company elected Mr. Knight a commercial vice-president in charge of what was then the New England district in 1936, and in 1946 he was assigned to the staff of the president of the company, in charge of co-ordination of the company's customer relations activities in New England. Mr. Knight was one of the organizers and the first president of the Electric Institute of Boston. He is a life trustee of Tufts College and a former officer of the Engineers' Club.

H. S. Vassar (A '06, M '18) laboratory engineer, testing laboratory, Public Service Electric and Gas Company, Maplewood, N. J., has retired after 44 years service with that and predecessor companies. Born at Flemington, N. J., on December 28, 1877, he was graduated from Pratt Institute in 1903. In that same year Mr. Vassar was employed as a draftsman with the United Electric Company, Newark, N. J., and in 1905 he was made an engineering assistant for that company. He rose to the position of assistant superintendent for the Public Service Railway Company, Newark, N. J., in 1908, but relinquished those duties in 1911 to assume those of laboratory engineer in the testing laboratory of the Public Service Electric Company, Newark, N. J., (the laboratory now is located in Maplewood). Mr. Vassar is a member of the American Society of Mechanical Engineers, and a member and past president of the American Society for Testing Materials. He is a member of the AIEE Standards committee for the year 1947–48.

Gloria Brooks (A '46) assistant projects engineer, Sperry Gyroscope Company, Great Neck, N. Y., was one of three recipients of the Sperry graduate scholarship plan awards for the year 1947–48. She holds a bachelor of science degree in electrical engineering from the Columbia School of Engineering and under the provisions of the Sperry plan will work toward her master's degree in electrical engineering at Columbia University. **S. B. Cohen** (A '44) staff member, radiation laboratory, Massachusetts Institute of Technology, Cambridge, Mass., also was named a recipient of this educational grant. He holds a bachelor of science degree in electrical engineering from the College of the City of New York and now is enrolled in Brooklyn Polytechnic Institute as a candidate for a master's degree in electrical engineering.

R. P. Brown (A '10, M '13) chairman of the board of Brown Instrument Company, Philadelphia, Pa., has been made a fellow of the American Society of Mechanical Engineers. He recently was awarded an honorary degree of doctor of engineering by the Drexel Institute of Technology.

J. F. Getz (A '43) formerly assistant to the president, I-T-E Circuit Breaker Company, Philadelphia, Pa., has been appointed sales manager for that company. A graduate of Pennsylvania State College, Mr. Getz has been associated with the I-T-E Circuit Breaker Company since 1944.

R. E. Murphy (A '42) formerly sales manager and member of the board of directors, I-T-E Circuit Breaker Company, Philadelphia, Pa., has been promoted to vice-president in charge of sales for that company. Mr. Murphy has been associated with that concern since 1934. Prior to that he had served as sales manager for the Esterline-Angus Instrument Company, Indianapolis, Ind., from 1922 to 1932. He is a member of the Association of Iron and Steel Engineers and of the National Electrical Manufacturers Association.

W. J. Fleming (A '43) formerly executive engineer, Trumbull Electric Manufacturing Company, Plainville, Conn., has been elected vice-president in charge of engineering for that company. Mr. Fleming has been associated with the concern since 1946. He previously had been with the

General Electric Company since his graduation from Pennsylvania State College in 1923. Mr. Fleming is a member of Tau Beta Pi, Eta Kappa Nu, and of the National Electrical Manufacturers Association.

T. F. McMains (A '34, M '44) formerly assistant vice-president, traffic department, Western Union Telegraph Company, New York, N. Y., has been appointed vice-president in charge of employee relations for that company. Mr. McMains, a graduate of the University of Illinois, entered the employ of the Western Union Company in 1927 as an engineering apprentice. He is a member of the American Management Association and of the Engineers' Club of New York.

Harris Reinhardt (M '42) formerly manager of the commercial engineering department, Sylvania Electric Products, Inc., New York, N. Y., has been named director of industrial relations for that concern. Mr. Reinhardt is chairman of the AIEE production and application of light committee for 1947–48.

OBITUARY • • • •

Vladimir Nikitich Karapetoff (A '03, M '12, F '12) emeritus professor of electrical engineering, Cornell University, Ithaca, N. Y., died on January 11, 1948. Born in St. Petersburg (now Leningrad) Russia, on January 8, 1876, Doctor Karapetoff was graduated with a civil engineering degree in 1897 from the Institute of Ways of Communications, St. Petersburg. He received a master of mechanical engineering degree from that same institute in 1902 after having studied electrical engineering at the Technische Hochschule, Darmstadt, Germany, from 1899 to 1900. He also had served as an instructor of electrical engineering and hydraulics in St. Petersburg from 1897 to 1902. Doctor Karapetoff was sent to the United States in 1902 by the Czarist Government as an engineering apprentice but remained to become a citizen in 1909. He was employed by the Westinghouse Electric Corporation (then the Westinghouse Company) Pittsburgh, Pa., as an apprentice from 1903 to 1904. He was appointed an assistant professor of electrical engineering at Cornell University in 1904 and was named a professor of electrical engineering at that institution in 1908. Doctor Karapetoff served as acting head of the engineering department at the school from 1912 to 1915. He retired in 1939. He was a nonresident lecturer on electric machinery at the United States Army Postgraduate School for Engineer Officers, Washington Barracks, D. C., from 1913 to 1916, and served as a visiting professor in the graduate school of the Polytechnic Institute of Brooklyn from 1930 to 1932. During the summers he held jobs in engineering departments of various companies and he served as a consulting engineer from time to time for several industrial concerns. Doctor Karapetoff was the inventor of many electric devices and had received the Montefiore Prize in 1923 and the Elliott Cresson Gold Medal of the Franklin Institute in 1927 for kinematic models of electric machinery for calculations. He was awarded an honorary doctor of music degree by the New York College of Music in 1934 and had served as a member of the advisory board for that school since 1936. He also received an honorary doctor of science degree in 1937 from the Polytechnic Institute of Brooklyn. Doctor Karapetoff contributed numerous papers and articles on scientific, engineering, ethical, political, educational, and musical topics. He wrote many engineering books and also completed a volume of poetry. He was talented on the piano and on the cello (to which he added a fifth string). Doctor Karapetoff was a member of Sigma Xi, Tau Beta Pi, Eta Kappa Nu, Phi Mu Alpha, American Association for the Advancement of Science, American Mathematical Society, Mathematical Association of America, American Association of University Professors, and of the American Physical Society. He served as a representative of the AIEE on the Council of the American Association for the Advancement of Science in 1936.

John Stanislaus Soares (A '09) Mountain View, Calif., died recently, according to word just received by the Institute, following a series of illnesses which he had had since his return to the United States after having been a prisoner of the Japanese in the Philippines for three years. Born in Hayward, Calif., on January 14, 1879, Mr. Soares was graduated from the University of California in 1901 with a bachelor of science degree in electrical engineering. He entered the employ of the Bay Counties Power Company (now part of the Pacific Gas and Electric Company) in 1901 and remained with them until 1904. Mr. Soares then was employed as an electrician for the Boston Machine Company, Oroville, Calif., and in 1905 was promoted to chief electrician for that concern. He next became associated with the Yuba Construction Company, Maupville, Calif., as chief electrician. In 1912 Mr. Soares went to Portugal for the Portuguese-American Tin Company to supervise the electrical installation on a tin dredge and upon completion of the work remained as superintendent until 1923. He worked on a dredge installation in Nome, Alaska, in 1924 and then was associated with the Red River Lumber Company, Westwood, Calif., as a master mechanic. From 1935 to 1941 he worked on dredge installation in California and in Montana. In 1941 Mr. Soares accepted a position as mechanical superintendent for the Benguet Mining Company, Automok, Philippine Islands. With the fall of Manila he was taken prisoner by the Japanese and placed in the prison camp at Santo Tomas, Manila, later being transferred to Camp Los Banos. Mr. Soares was rescued in 1945 and had been living in Mountain View since his return to the United States.

William L. Ludwick (A. '42, M '45) technical director, Peck, Stow, and Wilcox Company, Southington, Conn., died recently. He was born on January 3, 1894, in Leominster, England. Mr. Ludwick attended Kings College, London University, from 1918 to 1922, when he was graduated with a bachelor of science degree in both mechanical and electrical engineering. He was employed by the Budd Wheel Company, Philadelphia, Pa., in 1922 but left that concern in 1924 to accept a position as research and development engineer with the Brown Instrument Company, Philadelphia. In 1933 Mr. Ludwick was made chief consulting engineer to the Russian government for industrial instrumentation. He served in that capacity for three years and in 1936, when his second contract had been completed, he became associated with the firm of Negretti and Zambra as chief engineer at the Half Moon Works, Barnsbury, London, England. In 1938 Mr. Ludwick left that company to return to the United States where, in 1939, he accepted the position of design engineer with the Farnsworth Television and Radio Corporation, Fort Wayne, Ind. He was advanced to the capacity of chief mechanical engineer six months later but resigned in 1941 to become chief engineer of the newly formed instrument division of the Thomas A. Edison Company, West Orange, N. J. In 1942 Mr. Ludwick became associated with the company for whom he was employed at the time of his death. He was a member of the American Society of Mechanical Engineers, and of the American Society for Metals.

Herbert Appleton Wagner (A '98, M '03) former president and chairman of the board of the Consolidated Gas, Electric Light and Power Company of Baltimore, Md., died on December 5, 1947, in Garrison, Md. Born on February 24, 1867, in Philadelphia, Pa., he was educated at the Stevens Institute of Technology from which he received a mechanical engineering degree in 1887. He began his career as a construction engineer with the Westinghouse Electric and Manufacturing Company (now the Westinghouse Electric Corporation) Pittsburgh, Pa., in 1887, but left that concern in 1890 to become general superintendent of the Missouri Electric Light and Power Company (now the Missouri Edison Company) St. Louis. In 1891 Mr. Wagner organized the Wagner Electric Manufacturing Company, St. Louis, of which he later became the first president. He remained with that organization until 1900 when he opened a consulting engineering office in St. Louis. Mr. Wagner opened a consulting office in New York, N. Y., in the following year and was engaged in private practice until 1910. He relinquished this practice to undertake direction of the electric division of the Baltimore utility and served as vice-president of that concern until 1915 when he was elected

president of the organization. He was elected president and chairman of the board for that company in 1939 and resigned from the former position in 1942 and from the later position in 1943, when he retired. Mr. Wagner was the honorary chairman of the board of trustees of the Maryland Academy of Sciences, a trustee of the Stevens Institute of Technology, the Union Memorial Hospital, and of the Children's Hospital School. He was a former member of the executive committee of the Association of Edison Illuminating Companies, and a former trustee of the Edison Electric Institute.

Owen Augustine Havill (A '11, M '12, F '16) retired technical assistant for H. O. Schundler, New York, N. Y., died recently. Born on April 8, 1877, in New York, N. Y., he later attended Saint Francis Xavier's College, New York, N. Y., and was graduated in 1897 with a bachelor of arts degree. From 1897 to 1901 Mr. Havill was a student at the Columbia University school of applied science, New York, N. Y., from which he was graduated with an electrical engineering degree. After graduating in 1901 he became affiliated with the testing department and experimental railway of the General Electric Company, Schenectady, N. Y., and he remained with that company until 1904 when he was employed as an electrical assistant in the engineering department of the offices of F. S. Pearson, Consulting Engineer, New York, N. Y. He accepted a position in 1907 with the firm of Viele, Blackwell and Buck, Consulting Engineers, New York, N. Y., as an assistant electrical engineer. He was promoted to the position of electrical engineer in charge of the electrical part of that firm's consulting engineering in 1910, but left that position several years later to enter the employ of the New York, N. Y., office of the Anaconda Copper Mining Company. In 1921 Mr. Havill was transferred to the Chicago, Ill., office of that company but in the later part of the 1920's left that concern to accept a position with the West Lumber and Pulp Company, Portland, Oreg. He returned to New York City in 1921 when he first became associated with the firm of H. O. Schundler. Mr. Havill retired in 1937 and since that time had been living in East Orange, N. J. He was a member of the AIEE transmission and distribution committee for 1916–17.

Hiram Saine Foley (A '07, M '12) general manager, Motores, Ltd., Bogota, Colombia, South America, died recently. Born in Kingman, Kans., on January 21, 1885, Mr. Foley received his technical education through a course of study with the International Correspondence Schools and through general and technical reading. He was employed by the Mexican Central Railroad Company, Mexico, from 1900 to 1904 when he accepted a position with the Mexican Light and Power Company, Mexico City, Mexico, as foreman of a line construction gang. Seven months later he was promoted to assistant superintendent of the El Oro division and 8 months after that he was promoted to superintendent of that division. Then he was advanced to the position of superintendent of the San Ildefonso division of that company and later was made general superintendent but left that organization in 1914 to become superintendent of the distribution system of the Ebro Irrigation and Power Company, Barcelona, Spain. In 1916 Mr. Foley was named the New York representative for the Compagnie Generale d'Electricite of Paris, France. He remained with that concern until 1921 when he accepted a position as chief engineer with the Cia Hidroelectrica e' Irrigadora, Del Chapala South America, Guadalajara, Jalisco, Mexico. In 1925 Mr. Foley was affiliated with the Empresa de Luz y Fuerza Electrica, Guayaquil, Ecuador, South America, as manager, and in 1927 he accepted the position of vice-president and general manager for the Empresa Electrica del Ecuador, Inc., Guayaquil, Ecuador, South America. He was made vice-president and general manager for the Cia Colombiana de Electricidad, Barranquilla, Colombia, South America, in 1929 and remained with that company until 1940 when he assumed the position which he held at the time of his death. Mr. Foley was a member of the National Electric Light Association.

David Berger (A '28, M '45) secretary and treasurer, Berger Brothers Electric Motors, Inc., Rochester, N. Y., died recently. Born on August 30, 1895, in Rochester, N. Y., he received his technical education in public and service schools. Mr. Berger was employed by A. F. Bircher as an electric motor repairman from 1910 to 1912. From 1912 to 1913 he was in the employ of the Luitwieler Pumping and Engine Company as an apprentice machinist, from 1913 to 1914 with Green, Green, and Green as an electric motor repairman, from 1915 to 1917 with the Peerless Motor Car Company, Cleveland, Ohio, as chief night electrician and repairman, and from 1917 to 1919 with the Wheeler Green Electric Company as an electric motor repairman. Since 1920 Mr. Berger had served in the position which he held at the time of his death, and he also had served as secretary and treasurer for the Fred W. Kiemle Company, Toledo, Ohio since 1928.

William Harold Harden (A '15, M '19) operation and engineering department, American Telephone and Telegraph Company, New York, N. Y., died recently. Born in Martin, Mich., on June 9, 1889, Mr. Harden was awarded a bachelor of electrical engineering degree by the University of Michigan in 1912. He became affiliated with the American Telephone and Telegraph Company shortly after receiving his degree and was employed continuously by that concern until the time of his death. Mr. Harden had been in charge of transmission maintenance and results work on the headquarters staff since 1921. He had contributed articles to various technical publications and had received patents for several of his inventions. He was a member of Tau Beta Pi and the Montclair Society of Engineers, and was a registered professional engineer in New York State.

MEMBERSHIP . . .

Recommended for Transfer

The board of examiners, at its meeting of December 18, 1947, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the secretary of the Institute.

To Grade of Fellow

Chiles, J. H., Jr., div. engr., Westinghouse Elec. Corp., Sharon, Pa.
Crumley, H. L., chief engr., Virginia Elec. & Pr. Co., Richmond, Va.
Gussett, N. B., executive assistant, City Public Service Board, San Antonio, Tex.
Hess, W. F., prof. of metallurgical engg.; head, welding lab., Rensselaer Polytechnic Inst., Troy, N. Y.
Lampe, J. H., dean, school of engg., North Carolina State College, Raleigh, N. C.
Rosenbach, S., general engr., Duquesne Light Co., Pittsburgh, Pa.

6 to grade of Fellow

To Grade of Member

Babcock, G. M., asst. supt., electrical station maintenance, Dept. of Water & Power, City of Los Angeles, Calif.
Blake, W. J., Jr., rural engr., Virginia Public Service Co., Alexandria, Va.
Bush, J. E., owner & operator, Parker Electric Supply, Parker, Ariz.
Carey, J. G., transmitter supervisor, Jefferson Standard Broadcasting Co., Station WBT, Charlotte, N. C.
Cobb, E. E., elec. engr., Ebasco Services, Inc., New York, N. Y.
Compton, F. A., Jr., engr., D-C Armored Motor Engg. Div., General Elec. Co., Erie, Pa.
Cook, J. W., construction engr., A.T. & S.F. Ry. Co., Topeka, Kans.
Dinius, P. S., elec. engr., Chas. T. Main, Inc., Boston, Mass.
Fitz, O. R., chief engr., The Texas Co., Shanghai, China.
Gouchoe, R. L., elec. engr., Central Vermont Public Service Corp., Rutland, Vt.
Hartay, C. E., asst. to general supt. of distribution Duquesne Light Co., Pittsburgh, Pa.
Herchenroeder, L. W., industry engr., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Hill, V. E., electrical planning engr., Duquesne Light Co., Pittsburgh, Pa.
Hopkins, T. A., staff engr., Caterpillar Tractor Co., Peoria, Ill.
Jerome, B. A., elec. engr., Bemis Bag Co., Peoria, Ill.
Kiefer, W. M., engr., Commonwealth Edison Co., Chicago, Ill.
Knoop, W. A., Jr., treas. & field engr., Gawler-Knoop, Inc., Newark, N. J.
Lewis, D. C., elec. engr., Utica Div., C.N.Y.P. Corp., Utica, N. Y.
Lidow, E., vice pres. & chief engr., Selenium Corp. of America, Los Angeles, Calif.
MacFarlane, J. C., estimator, MacFarlane Elec., Santa Ana, Calif.
Mark, I., Jr., asst. branch chief, elec. industrial pr. & equip. branch, War Assets Admstra., New York, N. Y.
Pavely, W. T., senior engr., Cincinnati Gas & Elec. Co., Cincinnati, Ohio.
Perkins, C. M., project engr., Bendix Aviation Corp., Teterboro, N. J.
Plummer, C. B., chief television engr., F.C.C., Washington, D. C.

Powell, A. P., assoc. prof. elec. engg., Pennsylvania State College, State College, Pa.
Radin, E. L., product design engr., Control Commercial Co., Chicago, Ill.
Raney, J. R., general meter supt., Georgia Power Co., Atlanta, Ga.
Ransom, C. W., asst. section head, Pittsfield Works Lab., General Elec. Co., Pittsfield, Mass.
Rockfield, M. L., elec. engr., Aluminum Co. of America, Alcoa, Tenn.
Smiddy, H. F., partner, Booz, Allen & Hamilton, New York, N. Y.
Stanton, R. L., elec. supervisor, Veterans' Admstra., New York, N. Y.
Thompson, E. A., project engr., Westinghouse Elec. Corp., Sharon, Pa.
Watkins, N., electrical draftsman, Ford, Bacon & Davis, Charleston, W. Va.
Willis, E. S., member of technical staff, Bell Tel. Labs., New York, N. Y.

34 to grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Any member objecting to the election of any of these candidates should so inform the secretary before February 21, 1948, or April 1, 1948, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Member

Ackmann, H. H., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Ahmed, I. D., Public Works Dept., Electricity Branch, Lahore, Pakistan, India.
Baird, F. E., Northwestern Bell Tel. Co., Des Moines, Iowa
Bantau, J. W., Fox West Coast Theatres, Los Angeles, Calif.
Barbour, W. E., Jr., Tracerlab, Inc., Boston, Mass.
Barnes, C. B., City of Glendale, Glendale, Calif.
Bayles, J. W., A. Reyrolle & Co. Ltd., Hebburn-on-Tyne, England
Burfield, C. E., Consolidated Edison Co. of N. Y., Inc., New York, N. Y.
Coe, R. J., New England Power Service Co., Boston, Mass.
Cooke, H. A., Southland Paper Mills, Inc., Lufkin, Tex.
Deris, L. S., Mullenbach Elec. Mfg. Co., Los Angeles, Calif.
Gilman, W. C., W. C. Gilman & Co., New York, N. Y.
Gunsow, P. M., 132 Nassau St., New York, N. Y.
Hatch, O. F., Dept. of Water & Power, Los Angeles, Calif.
Hearn, R. B., Bell Tel. Lab., New York, N. Y.
Kerr, C., Jr., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Leggett, J. A., Westinghouse Elec. Corp., Springfield, Mass.
Mabey, C. A., The Bristol Co., Waterbury, Conn.
Manning, R. P., Surplus Line Adjusting Co., Los Angeles, Calif.
Martino, E. G., Glenn L. Martin Co., Middle River, Md.
Marty, H., Bernese Power Co., Inc., Berne, Switzerland
Matthews, W. H., E. I. Du Pont de Nemours & Co. Inc., Wilmington, Del.
McCrady, D. C., Canadian General Elec. Co., Ltd., Peterboro Ont., Canada
McKee, G. H., Western Union Tel. Co., Atlanta, Ga.
McMillan, W. R., Watson Labs., AMC, Eatontown, N. J.
Patel, C. M., Ordnance Factory, Dehra Dun, U. P., India
Propper, C. H., Propper Products Co., Kent, Ohio
Ropek, L. P., Selenium Corp. of America, Chicago, Ill.
Seehorn, L. E., Boeing Aircraft Co., Seattle, Wash.
Shoch, C. T., Pennsylvania Power & Light Co., Allentown, Pa.
Stevens, A. E., Kuhlman Elec. Co., Bay City, Mich.
Vose, F. C., Locke Insulator Corp., Baltimore, Md.
Wolfe, W. R., Okla. Gas & Elec. Co., Oklahoma City, Okla.
Wood, H. E., St. Anthony Mining & Development Co. Ltd., Tiger, Ariz.

34 to grade of Member

To Grade of Associate

United States, Canada, Mexico and Puerto Rico

1. North Eastern

Abbott, W. E., Fay, Spofford & Thorndike, Boston, Mass.
Anderson, L. R., Cornell Univ., Ithaca, N. Y.
Bartman, R., Jr., New England Tel. Co., New London, Conn.
Bass, R. F., Jr., General Elec. Co., Pittsfield, Mass.
Billings, J. D., General Elec. Co., Pittsfield, Mass.
Blanning, R. B., General Elec. Co., Schenectady, N. Y.
Boerstler, L. H., General Elec. Co., Schenectady, N. Y.
Brewer, L. C., New England Tel. & Tel. Co., Boston, Mass.
Britton, C. C., General Elec. Co., Pittsfield, Mass.
Burnham, W. H., General Elec. Co., West Lynn, Mass.
Campa, F. J., Stromberg-Carlson Co., Rochester, N. Y.
Canter, H. M., F.H.R.C. Theatrical Enterprises, Inc., Syracuse, N. Y.
Chandran, C. K., Intl. General Elec. Co., Schenectady, N. Y.
Clement, C. A., Public Service Co. of New Hampshire, Keene, N. H.
Collins, W. C., Liberty Mutual Ins. Co., Boston, Mass.
Crawshaw, R. C., New York Tel. Co., Albany, N. Y.
Cross, T. J., General Elec. Co., Schenectady, N. Y.
Crowe, F. S., Jr., General Elec. Co., Syracuse, N. Y.
Cummings, G. R., Associated Factory Mutual Fire Ins. Co., Boston, Mass.
Ellsworth, H. C., General Elec. Co., Pittsfield, Mass.
Faber, J. R., Jr., General Elec. Co., Schenectady, N. Y.
Eunson, S. E. (Miss), Link Aviation, Inc., Binghamton, N. Y.
Fernbach, J. D., I. B. M. Corp., Endicott, N. Y.
Foster, C. E., Taylor Instrument Cos., Rochester, N. Y.
Heitman, E. J., Boston Edison Co., Boston, Mass.
Horn, P. R., General Elec. Co., Schenectady, N. Y.
Jackson, S. P., General Elec. Co., Lynn, Mass.
Jones, P. D., New York Tel. Co., Watertown, N. Y.
Landall, L. B., Northeastern Univ., Boston, Mass.
Mann, L. G., Mass. Inst. of Tech., Cambridge, Mass.
Mirand, A. J., White Bros. Rose Corp., Medina, N. Y.
Neyhard, J. F., I. B. M. Corp., Endicott, N. Y.
Nightingale, J., Metropolitan Vickers Elec. Co. Ltd., England, c/o General Elec. Co., Schenectady, N. Y.
Packard, C. P., Crocker Wheeler Elec. Mfg. Co., Boston, Mass.
Pohl, R. V., General Elec. Co., Schenectady, N. Y.
Robinson, R. D., General Elec. Co., Syracuse, N. Y.
Rosenberg, R. L., General Elec. Co., Pittsfield, Mass.
Salay, J., Neff Elec. Co., Niagara Falls, N. Y.
Schwarz, P. D., General Elec. Co., Schenectady, N. Y.
Spencer, G. R., Cornell Univ., Ithaca, N. Y.
Stern, H. L., General Elec. Co., Pittsfield, Mass.
Teller, C. L., Scovill Mfg. Co., Waterbury, Conn.
Timo, D. P., General Elec. Co., Fitchburg, Mass.
Tunnicliffe, W. W., Boston Univ., Boston, Mass.
Turner, F. J., General Elec. Co., Pittsfield, Mass.
Vogel, J. R., Jr., Central Hudson Elec. & Gas Corp., Poughkeepsie, N. Y.
Wells, L. A., Narragansett Elec. Co., Providence, R. I.
White, J. C., General Elec. Co., Schenectady, N. Y.
Wright, W. J., Conn. Valley Power Exchange, Hartford, Conn.

2. Middle Eastern

Artun, M. A., General Elec. Co., Erie, Pa.
Audouin, R. J., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Barnhart, H. D., General Elec. Co., Erie, Pa.
Beckner, C. J., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Berger, L. L., Naval Ordnance Lab., Washington, D. C.
Bernstein, M., Ohio Edison Co., Akron, Ohio
Bonsall, R. B., Brown Instrument Co., Philadelphia, Pa.
Boyer, D. H., Baltimore Transit Co., Baltimore, Md.
Brinks, J. W., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Brown, H. E. (re-election), The Ohio Power Co., Canton, Ohio
Bryan, J. R., Jr., Toledo Edison Co., Toledo, Ohio
Bugianesi, A. J., Murray Corp. of America, Scranton, Pa.
Clapp, D. E., Elec. Service Mfg. Co., Philadelphia, Pa.
Clark, R. A., Jr., Westinghouse Elec. Corp., Pittsburgh, Pa.
Colbert, L. H., Harry J. Fisher & Assocs., Cleveland, Ohio
Coleman, W. E., Carnegie-Illinois Steel Corp., Pittsburgh, Pa.
Duich, J. M., Kelly-Koet Mfg. Co., Cleveland, Ohio
Ellis, T. E., North Elec. Mfg. Co., Kenton, Ohio
Erwin, W. W., I-T-E Circuit Breaker Co., Philadelphia, Pa.
Faucett, R. E., Cleveland Elec. Illuminating Co., Cleveland, Ohio
Fleming, F. J., Westinghouse Elec. Corp., Sharon, Pa.
Frick, B., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Garcia, V. A., The North Elec. Mfg. Co., Kenton, Ohio
Gardner, E. W., Baltimore Transit Co., Baltimore, Md.
Griask, F. R., Delco Products, Dayton, Ohio
Hart, W. C., Kingston Conley Elec. Co., Cambridge, Ohio
Hauser, A. F., Duquesne Light Co., Pittsburgh, Pa.
Hausburg, A., The Ohio Power Co., Canton, Ohio
Herrmann, J. E., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Heyman, R., American Totalisator Co., Baltimore, Md.
Hoffman, H. S., Jr., Brown Instrument Co., Philadelphia, Pa.
Hohrein, W. C., Baltimore Transit Co., Baltimore, Md.
Humphreys, R. L., Goodyear Tire & Rubber Co., Akron, Ohio
Igen, L., Duquesne Light Co., Pittsburgh, Pa.
Johnston, J. S., Jr., General Elec. Co., Philadelphia, Pa.
Jones, A. L., Sun Oil Co., Philadelphia, Pa.
Jones, W. H., Sun Oil Co., Philadelphia, Pa.
Kaczmarcsik, P., Moore School, Univ. of Pennsylvania, Philadelphia, Pa.
Klein, G., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Leser, F. A., Jr., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Looft, F. J., Jr., Republic Steel Corp., Cleveland, Ohio
Lydick, H. W., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Martin, H. W., Ohio Brass Co., Mansfield, Ohio
Maskiell, F. H., Pennsylvania Transformer Co., Canonsburg, Pa.
McConnell, H. M., Carnegie Inst. of Tech., Pittsburgh, Pa.
McCown, W. E., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Parkin, H. G., Jr., Philadelphia Elec. Co., Philadelphia, Pa.
Pastell, D. L., E. I. du Pont de Nemours & Co., Penns Grove, N. J.
Poulson, D. V., Goodyear Tire & Rubber Co., Akron, Ohio
Ray, F. H., Philadelphia Elec. Co., Philadelphia, Pa.
Rolfking, J. A., Jr., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Ryon, M. G., North Elec. Mfg. Co., Kenton, Ohio
Sartore, G., The Hoover Co., No. Canton, Ohio
Schipper, R. J., Crosley Div., AVCO, Cincinnati, Ohio
Shrider, K. L., Reliance Elec. & Engg. Co., Cleveland, Ohio
Sims, R. U., Westinghouse Elec. Corp., Wilkinsburg, Pa.
Speer, L. E., The Ohio Power Co., Canton, Ohio
Spurney, R. V., Reliance Elec. & Engg. Co., Cleveland, Ohio
Stanley, M. J., North Elec. Mfg. Co., Kenton, Ohio
Stewart, J. F., Leeds & Northrup Co., Philadelphia, Pa.
Stinson, D. C., Locke Insulator Corp., Baltimore, Md.
Taylor, J. J., Baltimore Transit Co., Baltimore, Md.
Thigpen, W. L., Jr., Pennsylvania Railroad Co., Altoona, Pa.
Tussey, T. F., Swindell Dressler Corp., Pittsburgh, Pa.
Van Gorkom, J. H., Cincinnati Gas & Elec. Co., Cincinnati, Ohio
Vendur, T. J., Hartford Steam Boiler Inspection & Ins. Co., Cleveland, Ohio
Wall, V. W., Penn State College, State College, Pa.
Whitt, B. R., E. I. du Pont de Nemours & Co., Charleston, W. Va.
Wick, R. S., Reliance Elec. & Engg. Co., Cleveland, Ohio
Yost, F. A., McNally-Pittsburgh Mfg. Co., Pittsburgh, Pa.
Zimmerli, F. H., Univ. of Pennsylvania, Moore School, Philadelphia, Pa.

3. New York City

Adler, R., Cyclohm Motor Corp., Long Island City, N. Y.
Bean, J. W., American Gas & Elec. Service Corp., New York, N. Y.
Bernstein, B., Amperex Electronic Corp., Brooklyn, N. Y.
Bill, G. C., American Tel. & Tel. Co., New York, N. Y.
Bleshman, N., Ebasco Services, Inc., New York, N. Y.
Boone, C. C., Ebasco Services, Inc., New York, N. Y.
Brown, E. L., Sylvania Elec. Products, Inc., Kew Gardens, N. Y.
DeMarth, E. E., Brundy Engg. Co. Inc., New York, N. Y.
D'Amato, R. J., Ford Instrument Co., Long Island City, N. Y.
Dexheimer, R. G., Westinghouse Elec. Corp., Newark, N. J.
Dornhoefer, W. J., Ward Leonard Elec. Co., Mt. Vernon, N. Y.
Drowne, H. B., Public Service Comm., New York, N. Y.
Eaker, L. C., Western Elec. Co., Kearny, N. J.
Epstein, H., C. C. N. Y., New York, N. Y.
Fischer, J. E., Western Elec. Co., New York, N. Y.
Forberg, T., George G. Sharp, New York, N. Y.
Gitz, J. R., Public Service Elec. & Gas Co., Newark, N. J.
Gordon, R. H., Bigelow-Sanford Carpet Co., Inc., New York, N. Y.
Johnson, R. L., Jr., Public Service Elec. & Gas Co., Jersey City, N. J.
Kline, A. L. (Miss), Ebasco Services Inc., New York, N. Y.
Koffman, H. J., Kelley-Koett Intl. Corp., New York, N. Y.
Krugman, L. M., Western Elec. Co., Newark, N. J.
Landauer, W. E., Columbia Univ., New York, N. Y.
Liberatore, S. N., J. G. White Engg. Co., New York, N. Y.
Meisler, S. L., F. L. Smidth & Co., New York, N. Y.
Padalino, J. J., Newark College of Engg., Newark, N. J.
Scharff, L., EDO Corp., College Point, L. I., N. Y.
Shapiro, S., Polytechnic Inst. of Bklyn, Brooklyn, N. Y.

Steele, H., Jarcho Bros, Inc., New York, N. Y.
Steiler, P. H., Federal Tel. & Radio, Clifton, N. J.
Tchou, M., Manhattan College, New York, N. Y.
Tuomola, R. G., Wallace & Tiernan Co., Inc., Belleville, N. J.
Walker, B., Marine Elec. Corp., Brooklyn, N. Y.
Walker, T. C., Watson-Flagg Engg. Co., New York, N. Y.
Weisman, I. C. C. N. Y., New York, N. Y.
Weeks, W. G., Worthington Pump & Machinery Corp., Harrison, N. J.
Williams, J. B., Jr., Ensign, USS Mississippi, c/o FPO, New York, N. Y.
Woodford, B. B., Johns-Manville Sales Corp., New York, N. Y.

4. Southern

Agee, G. A., Carbide & Carbon Chem. Corp., Oak Ridge, Tenn.
Baker, R. A., Elec. Constructors, Inc., Pascagoula, Miss.
Booth, H. F., Carbide & Carbon Chem. Corp., Oak Ridge, Tenn.
Briesemeister, R. E., Georgia School of Tech., Atlanta, Ga.
Brooks, W. T., Carbide & Carbon Chemicals Corp., Oak Ridge, Tenn.
Burdoin, J. F., Minnesota Power & Light Co., Duluth, Minn.
Burke, S. M. S., Alabama Power Co., Winfield, Ala.
Burns, H. D., Alabama Power Co., Birmingham, Ala.
Campbell, J. C., Jr., Nashville Elec. Service, Nashville, Tenn.
Donaldson, M. R., Georgia School of Tech., Atlanta, Ga.
Drexel, A., Florida Power & Light Co., Miami, Fla.
Drummond, C. L., Georgia Power Co., Atlanta, Ga.
Halstead, W. R., Conditioned Air Engineers, Inc., Atlanta, Ga.
Harris, J. G., Paul O. Rottmann, Shreveport, La.
Hathaway, S. D., Virginia Poly. Inst., Blacksburg, Va.
Holcombe, M. E., R. H. Bouligny, Inc., Wytheville, Va.
Jones, C. E., Carbide & Carbon Chem. Corp., Oak Ridge, Tenn.
Lacefield, W. R., Ingalls Shipbuilding Corp., Birmingham, Ala.
Lewis, J. B., Duke Univ., Durham, N. C.
Maxwell, R. G., Carbon & Carbide Chemicals Corp., Oak Ridge, Tenn.
Meagher, A., TVA, Chattanooga, Tenn.
Morgan, H. L., Jr., Clemson College, Clemson, S. C.
Mowry, K. W. (re-election), Firestone Tire & Rubber Co. of Tenn., Memphis, Tenn.
Perrone, A. J., Jr., South Carolina Elec. & Gas Co., Columbia, S. C.
Rifkin, A. R., TVA, Wilson Dam, Ala.
Robison, C. E., Tenn. Coal, Iron & Railroad Co., Fairfield, Ala.
Rosenberg, P. H., Abbeville Mills Corp., Abbeville, S. C.
Smith, J. A., Carbide & Carbon Chem. Corp., Oak Ridge, Tenn.
Spencer, J. E., Southern Bell Tel. & Tel. Co., Birmingham, Ala.
Stephens, J. R., Champion Paper & Fibre Co., Canton, N. C.
Thompson, H. C., Carbide & Carbon Chem. Corp., Oak Ridge, Tenn.
Vaughan, J. W., Appalachian Elec. Power Co., Roanoke, Va.
Venable, W. B., E. Barrett Foster, Sheffield, Ala.
West, C. V. (re-election), Virginia Elec. & Power Co., Norfolk, Va.
Whipple, B. J., Flint Elec. Membership Cooperation, REA, Reynolds, Ga.
Wicker, T. P., Jr., Carbon & Carbide Chemical Corp., Oak Ridge, Tenn.
Williams, R. B., Jr., U. S. Naval Proving Ground, Dahlgren, Va.

5. Great Lakes

Anderson, R. W., Commonwealth Edison Co., Chicago, Ill.
Augustson, W., Public Service Co. of Northern Illinois, Wheaton Ill.
Austin, C. L., Milwaukee School of Engg., Milwaukee, Wis.
Burnett, J. R., Purdue Univ., Lafayette, Ind.
Diefenbach, R. F., Michigan Bell Tel. Co., Detroit, Mich.
Drake, A. M., Northern States Power Co., Minneapolis, Minn.
Foecke, H. A., Iowa State College, Ames, Iowa
Frier, B. E., Electro-Motive Div., General Motors, La Grange, Ill.
Gaumer, L. S., Pilgrim Distributing Co., Peoria, Ill.
Giedt, W. R., General Elec. Co., Fort Wayne, Ind.
Harcus, G. A., Commonwealth Edison Co., Chicago, Ill.
Hatch, S. S., Commonwealth & Southern Corp., Jackson, Mich.
Haynes, A. G., Corn Products Refining Co., Chicago, Ill.
Healy, C. F., Ralph D. Thomas & Assocs., Inc., Minneapolis, Minn.
Jack, J., Public Utility Engg. & Service Corp., Chicago, Ill.
Jarzembski, W. B., Staley Mfg. Co., Decatur, Ill.
Johnson, J. M., Caterpillar Tractor Co., Peoria, Ill.
Ketelsen, D. F., Iowa Public Service Co., Le Mars, Iowa
King, R. E., Square D Co., Milwaukee, Wis.
Krieger, E. J., Univ. of Ill., Urbana, Ill.
Larson, R. L., Purdue Univ., West Lafayette, Ind.
Mendel, F. S., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Meyer, M. V., Caterpillar Tractor Co., Peoria, Ill.
Miller, C. E., Intl. Detrola Corp., Detroit, Mich.
Modry, J. F., Electro-Motive Div. General Motors, La Grange, Ill.
Mueller, E. W., Apt. 203, Badger, Wis.
Novak, L. L., Kuhlman Elec. Co., Bay City, Mich.
Orestsen, F. P., Illinois Elec. & Gas Co., Rockford, Ill.
Pederson, J. J., Zenith Radio Corp., Chicago, Ill.
Pickering, L. W., Commonwealth & Southern Corp., Jackson, Mich.
Rahman, S. M. F., Civil Aeronautics Administration, Chicago, Ill.
Schowe, L. F., Sr., General Elec. Co., Fort Wayne, Ind.
Sell, H. H., Westinghouse Elec. Corp., Minneapolis, Minn.
Seven, H. C., Caterpillar Tractor Co., Peoria, Ill.
Sirvatka, W. E., Public Utility Engg. & Service Co., Chicago, Ill.
Strom, D. E., Carnegie-Illinois Steel Corp., Chicago, Ill.
Woznicki, E. T., Indiana Michigan Elec. Co., South Bend, Ind.

6. North Central

Joshi, A. S., U. S. Bureau of Reclamation, Denver, Colo.
Lichtenwalter, J. E., Cheyenne Light, Fuel & Power Co., Cheyenne, Wyo.

7. South West

Appell, W. M., Southwestern Bell Tel. Co., Dallas, Tex.
Berean, R. A., H. N. Roberts & Assocs., Lubbock, Tex.
Blair, W. B., Schlumberger Well Surveying Corp., Houston, Tex.
Brown, H. K., Dow Chemical Co., Freeport, Tex.
Constant, P. C., Railway Radio-Tel., Inc., Kansas City, Mo.
Crawford, W. M., Gulf States Utilities Co., Beaumont, Tex.
Deck, J. B., Jr., Houston Lighting & Power Co., Houston, Tex
Gardner, J. E., Arkansas Power & Light Co., Searcy, Ark.
Gilliam, R. C., West Texas Utilities Co., Abilene, Tex.
Goldsand, W., S. C. Sachs Co., Inc., St. Louis, Mo.
Handley, P. J., Missouri Public Service Corp., Sedalia, Mo.
Hobbs, E. G., Public Service Co. of Okla., Lawton, Okla.
Homan, C. C., Jr., El Paso Natural Gas Co., El Paso, Tex.
Kline, V. A., Lockwood & Andrews, Houston, Tex.
Manning, W. B., Jr., Southwestern Gas & Elec. Co., Longview, Tex.
McNair, C. R., Jr., Stanolind Oil & Gas Co., Tulsa, Okla.
McRae, J. P., Adams Field, Little Rock, Ark.
Murdock, L. A., Lower Colorado River Authority, New Braunfels, Tex.
Mullins, W. H., Jr., Univ. of New Mexico, Albuquerque, New Mex.
Naramore, H. F., Kansas Gas & Elec. Co., Pittsburgh, Kans.
Pitts, J. R., Shell Oil Co., Houston, Tex.
Reeves, J. D., Okla. Gas & Elec. Co., Enid, Okla.
Rust, D. W., Natl. Industrial Service Assn., St. Louis, Mo.
Schneider, R. C., Southwestern Bell Tel. Co., Dallas, Tex.
Smith, R. V., Okla. Gas & Elec. Co., Oklahoma City, Okla.
Vockrodt, Q., U. S. Engineers, Tulsa, Okla.
Wylie, J. E., Southwestern Bell Tel. Co., St. Louis, Mo.
Young, T. C., Anderson-Young Elec. Co., Lubbock, Tex.

8. Pacific

Blundell, A. C., Maydwell & Hartzell Inc., Los Angeles, Calif.
Burton, J. J., Coast Counties Gas & Elec. Co., Santa Cruz, Calif.
Campbell, R. M., Chamber of Commerce, Oakland, Calif.
Clanton, W. H., Southern California Edison Co., Alhambra, Calif.
Denning, R. H., U. S. Bureau of Reclamation, Boulder City, Nev.
Finton, F. O., General Petroleum Corp., Los Angeles, Calif.
Garner, C., N. O. T. S., Inyokern, Calif.
Gillham, D. G., Pacific Gas & Elec. Co., San Jose, Calif.
Haupt, L. O., Jr., Procter & Gamble, Long Beach, Calif.
Heidrick, H. H., Pacific Gas & Elec. Co., Eureka, Calif.
Herzer, R. L., Pacific Gas & Elec. Co., San Rafael, Calif.
Howison, W. W., Warrens Elec. Co., Los Angeles, Calif.
Lemmon, M. P., United Engg. Co., Alameda, Calif.
Loos, D. D., Stone & Webster Engg. Corp., Vernon, Calif.
McCroskey, W. N., General Elec. Co., Oakland, Calif.
Miller, C. N., Naval Electronics Lab., San Diego, Calif.
Mitchell, R. G., Square D Co., San Francisco, Calif.
Morgan, J. T., Pacific Gas & Elec. Co., Eureka, Calif.
Neher, E. E., Pacific Gas & Elec. Co., San Francisco, Calif.
Neumann, C. F., Guy F. Atkinson Co., Henderson, Nev.
Paull, A., The Pacific Tel. & Tel. Co., Los Angeles, Calif.
Sharpe, V. G., Pacific Gas & Elec. Co., Burney, Calif.
Penniman, A. B., Penniman & Richards, San Jose, Calif.
Shaw, C. F., Dept. of Water & Power, Los Angeles, Calif.
Smith, E. D. Shell Oil Co., Bakersfield, Calif.
Stavert, T. C., Southern Calif. Edison Co., San Bernardino, Calif.
Stumph, J. H., U. S. Rubber Co., Los Angeles, Calif.
Turner, J. O. (re-election), Zinsco Elec. Products, San Francisco, Calif.
Wade, E. C., North American Aviation, Inc., Los Angeles, Calif.
Wolfangle, H. H., Pacific Elec. Mfg. Corp., San Francisco, Calif.
Zieharth, J. A. III, Standard Oil Co. of Calif., San Francisco, Calif.

9. North West

Armstrong, A. A., Oregon State College, Corvallis, Oreg.
Barnes, L. P., Telluride Power Co., Richfield, Utah
Bason, W. C., General Elec. Co., Portland, Oreg.
Belshaw, G. M., The Pacific Tel. & Tel. Co., Portland, Oreg.
Gordon, W. E., Portland General Elec. Co., Portland, Oreg.
Grady, R. E., Weyerhaeuser Timber Co. Tacoma, Wash.
Hammond, S. B., Univ. of Utah, Salt Lake City, Utah
Hickenlooper, F. T., Geneva Steel Co., Geneva, Utah
Lawton, W. E., Aluminum Co. of America, Vancouver, Wash.
Newhouse, N. W., Portland General Elec. Co., Oregon City, Oreg.
Norlin, J. W. A., Central Elec. Cooperative, Inc., Redmond, Oreg.
Olsen, A. P., Telluride Power Co., Milford, Utah
Olson, W. J., (re-election), City of Seattle, Seattle, Wash.
Ricks, C. R., Bureau of Reclamation, Helena, Mont.
Robbins, F. D., Univ. of Washington, Seattle, Wash.
Staley, R. N., Puget Sound Power & Light Co., Chehalis, Wash.
Todd, H. E., The Pacific Tel. & Tel. Co., Portland, Oreg.
Zimmerman, O. F., Portland General Elec. Newberg, Oreg.
Zolling, G. F., Pacific Tel. & Tel. Co., Portland, Oreg.

10. Canada

Bushfield, R. E., Canadian Westinghouse Co. Ltd., Hamilton, Ont., Canada
Carter, A. G., Canadian Westinghouse Co., Ltd., Hamilton, Ont., Canada
Dowling, G. L., Hydro-Elec. Power Comm. of Ont., Toronto, Ont., Canada
Gill, W. D., B. C. Elec. Railway Co., Ltd., Vancouver, B. C., Canada
Goodhead, E. A., Hydro-Elec. Power Comm. of Ont., Toronto, Ont., Canada
Holder, S. P., Shawinigan Water & Power Co., Montreal, Que., Canada
Krufka, A., Bowater's Nfl'd Paper & Pulp Mills, Ltd., Cornerbrook, Newfoundland, Canada
LeBourdais, R., Quebec Hydro-Elec. Comm., Montreal, Que., Canada
McHardy, R. J., Hydro-Elec. Power Comm. of Ontario, Toronto, Ont., Canada
Pike, S. W., Canadian Line Materials, Scarboro Junction, Ont., Canada
Slemon, G. R., Univ. of Toronto, Toronto, Ont., Canada

Elsewhere

Aswath, M., Govt. of Mysore, Bangalore, South India
Basu, S. K., Municipal Elec. Undertaking, Raipur C. P., India
Brigden, K. C., The Northampton Elec. Light & Power Co. Ltd., Towcester, Northants, England
Harakis, A. J., 23A Enoseos St., Limassol, Cyprus
Hart, T. W. G., Imperial Chemical Industries Ltd., c/o A. Reyrolle & Co. Ltd., Hebburn, England
Iyengar, K. R. K., Civil Aviation Dept., Govt. of India, Bangalore City, India
Maas Geesteranus, J. A., Intl. General Elec. Co., Batavia, Java
Singh, L. B., Govt. Electricity Dept., C. P. Berar, Nagpur, India
Ting, S. N., Central Elec. Mfg. Co. of China, Shanghai, China
Wilson, S. B. A., Compagnie Francaise de l'Afrique Occidentale, Accra, Gold Coast, Africa

Total to grade of Associate
United States, Canada, Mexico and Puerto Rico, 323
Elsewhere, 10

AIEE Technical Subcommittees

Previous issues of *ELECTRICAL ENGINEERING* have carried information regarding the new AIEE committee structures. An explanation of the main committee organization (*EE, Oct '47, pp 1006–11*), the list of officers and committees with their personnel (*EE, Oct '47, pp 1031–35*), and the scope and personnel of the power group subcommittees (*EE, Jan '48, pp 106–09*) have been covered.

The following list, naming the subcommittees of the industry group, communication and science group, and the general applications group, substantially completes the listing of all the AIEE technical subcommittees.

Industry Group Subcommittees

Chemical, Electrochemical, and Electrothermal Committee

1. Arc Furnaces and Electrothermal Processes Subcommittee

F. R. Benedict, *chairman* — J. E. Hobson
W. L. Bundy — W. B. Kouwenhoven
E. H. Browning, Jr. — A. R. Oltrogge
E. A. Hanff — E. Scheick

2. Cathodic Protection Subcommittee

Scope: To develop the electrical engineering aspects of the application of cathodic protection. To promote a general understanding of those factors, under the control of designing and operating engineers, that contribute to corrosion and to its mitigation. To prepare a technical paper on the subject of electrical design from the standpoint of reduction of corrosion.

E. L. Kirk, *chairman* — I. A. Dennison
A. E. Archambault — L. J. Gorman
J. D. Brance — T. G. Hieronymus
A. S. Brooks — R. J. Kuhn
Guy Canfield — D. H. Levy
C. G. Cox — R. L. Rayner
H. W. Wahlquist

3. Electrolytic Processes Subcommittee

Scope: Treatment of all matters relative to electrolytic processes such as electrodeposition, electrolytic refining, electrolytic reduction, alkali chloride electrolysis, aqueous electrolytic processes. Such subjects as theory, technique, efficiency, plant, electrolytic cells, application of power conversion equipment, specialized equipment, and operating hazards are within the scope of this subcommittee.

F. L. Lawton, *chairman* — J. Elmer Housley
W. E. Gutzwiller, *secretary* — Rollin Kennard
F. L. Fletemeyer — G. H. Orcutt
Felix Glaza — Waldo Porter
J. D. Harper — G. B. Scheer
H. E. Houck — J. Tompkins

4. Metallic Rectifiers Subcommittee

Scope: This subcommittee so far has completed a set of standard definitions, a bibliography, and a patent list on metallic rectifiers. It is working now on a test code and also is collaborating with the United States Army and Navy in connection with the issuance of a Joint Army-Navy specification on metallic rectifiers. This subcommittee has future plans to issue standards for metallic rectifiers, as well as delve into the theoretical aspects of these rectifiers.

L. O. Grondahl, *chairman* — C. W. Hansell
E. A. Harty, *secretary* — C. G. Herskind
W. F. Bonner — W. E. Phillips
L. W. Burton — N. Y. Priessman
P. G. Cobb — C. G. Ramsey
M. E. Gamble — I. R. Smith
K. S. Geiges — D. Truckses
E. A. Groeteke — J. Yarmack
C. E. Hamann — S. Zwerling

5. Petroleum Refining and Production Subcommittee

Lester Goldsmith, *chairman* — E. L. Hoyle
H. J. Appel — D. H. Levy
W. H. Dickinson — E. L. Nopper
J. B. Glasby — L. E. Priester

6. Storage Batteries Subcommittee

Scope: This subcommittee has as its function the fostering of technical papers and the establishment of AIEE Standards, where needed, on all phases of storage battery design and engineering.

H. C. Riggs, *chairman* — E. T. Rummel
J. D. Huntsberger — J. J. Unger
L. A. Murray — H. H. Zielinski — K. A. Vaughn

7. Voltage Transients in Arc Furnace Circuits Subcommittee

E. R. Whitehead, *chairman*

Electric Heating Committee

1. Electronic Heating Subcommittee

Scope: Study of the problem of interference from electronic heating equipment (with the advice of the electronic heating subcommittee, the Federal Communications Commission has formulated regulations regarding the allowable limit of radiation from electronic heating equipment). Formulation of the principles of good engineering practice to deal with intolerable interference. Development of an AIEE Standard for electronic heating equipment including definitions of electronic heating terms.

W. C. Rudd, *chairman* — R. J. Hunn
Marvin Boch — T. R. Kennedy
G. P. Bosomworth — H. F. Kincaid
L. W. Chapin — T. P. Kinn
F. G. DeRogg — F. M. Rugg
H. E. Dinger — G. W. Scott, Jr.
L. M. Duryee — J. T. Thwaites
J. E. Eiselein — D. E. Watts
W. H. Hickok — A. C. Wooldridge — Otto Weitmann

2. Radiant Heating Subcommittee

Scope: Standardization of lamp-type heating in all its phases. The advantages and limitations of infrared heating will be emphasized for the benefit of the engineering profession. It will cover the construction, optics, thermodynamics, and safety considerations associated with all high temperature sources, correlation with other forms of electric heating, but not to include space heating.

Paul H. Goodell, *chairman* — J. E. Johanson
I. J. Barber — E. A. Lindsay
E. J. Bates — A. D. Moore
Earl Benson — C. T. Prendergast
P. O. Blackmore — C. E. Russell
H. J. Garber — G. W. Scott, Jr.
E. D. Haigler — J. E. Sump
S. G. Hibben — Ernest Upton
W. H. Wagner

3. Radiation Measurements Above 200 Megacycles Subcommittee

Scope: All methods of measuring radiation up to and above 200 megacycles are being studied. Actual experimental work in various laboratories is being undertaken to develop methods of measurement in the frequency ranges where a satisfactory method does not now exist and to improve methods in those ranges where some work has been done to date.

R. M. Baker, *chairman* — C. W. Frick
H. H. Beizer — G. A. Miller
Marvin Boch — H. E. Revercomb
E. W. Chapin — G. W. Scott, Jr.
H. E. Dinger — Ralph M. Showers
J. E. Eiselein — H. E. Sorrows

4. Resistance Heating and Electric Furnaces Subcommittee

Scope: To study and promulgate information on the use of resistance heating and electric furnaces in industry, including such standardization as may be necessary.

L. P. Hynes, *chairman* — A. G. Hotchkiss
F. E. Bash — C. E. Peck
Mark Greer — K. Pinder
J. C. Handy — David Y. Robinson

Electric Welding Committee

1. Power Supply for Resistance Welding Machines Subcommittee

Scope: Provision of basic information relating to power requirements and the effect of resistance welding load from the standpoint of both users and utilities. Outline economic considerations in the purchase and utilization, as well as provision of power, for welding including power factor correction, combined power and welding facilities, and so forth. Set up desirable practices and methods of procedure to be used in the selection of adequate power facilities for resistance welding.

C. M. Rhoades, Jr., *chairman* — P. A. Duchastel
W. H. Allen — R. H. Phair
W. G. Bostwick — C. E. Smith
C. N. Clark — C. B. Stadum
E. F. Dissmeyer — H. W. Tietze
Myron Zucker

2. Resistance Welding Subcommittee

C. E. Smith, *chairman* — C. N. Clark
E. M. Callender — G. W. Garman
Myron Zucker

3. Arc Welding Subcommittee

E. F. Steinert, *chairman* — R. R. LoBosco
C. N. Clark — C. I. MacGuffie
E. L. Hansen — H. W. Snyder

General Industry Applications Committee

1. Machine Tools Subcommittee

W. B. Wigton, *chairman* — J. M. Dickenson
R. T. Anderson — L. W. Herchenroeder
E. L. Bailey — E. F. Mekelburg
J. M. Delfs — D. R. Percival
R. E. Stroppel

2. Materials Handling Subcommittee

E. M. Hayes, *chairman* — D. C. Gray
E. L. Blankenbeker, *secretary* — R. W. Mallick
Fred W. Atz — A. H. Myles
O. M. Bundy — E. J. Posselt
M. A. de Ferranti — E. C. Rice
E. O. Dunham — C. B. Rissler
T. O. English — G. W. Yanney

3. Pulp and Paper Industry Subcommittee

G. W. Knapp, *chairman* — Floyd L. Davis
V. B. Baker — Oscar O. Fisk
H. B. Barrow — E. K. Murphy
A. C. Bird — H. Ostertag
D. C. Christison — H. A. Rose
Ray Smith

4. Rubber and Plastics Industries Subcommittee

K. W. John, *chairman* — V. O. Johnson
A. T. Bacheler — G. V. Kulligren
P. S. Bechtol — B. D. Morgan
B. J. Dalton — W. J. Secrest
J. A. Gienger — H. L. Smith
R. F. Snyder

5. Textile Industry Subcommittee

F. D. Snyder, *chairman* — L. T. Jester
S. A. Bobe — A. P. Lewis
R. J. Demartini — D. McConnell
A. W. Frankenfield — Victor Sepavich
H. Haley — R. S. Stribling
F. B. Hauesler — H. C. Uhl

Industrial Control Committee

1. Bibliography Subcommittee

R. W. Jones, *chairman*

2. Electronic Control Subcommittee

Scope: The treatment of all matters in which the dominant factors are the design, construction, and functioning of electronic industrial controls exclusive of those controls and functions that specifically are assigned to other technical committees.

H. L. Palmer, *chairman* — F. G. Logan
F. T. Bailey — E. B. McDowell
H. B. Black — J. W. Picking
S. L. Burgwin — V. J. Porter
C. J. Collom — K. P. Puchlowski
Ben Cooper — W. G. Roman
E. T. Davis — C. A. Schurr
W. H. Elliot — W. W. Snyder
William Few — H. I. Stanback
E. W. Hutton — B. B. Stuart
L. U. C. Kelling — C. M. Summers
O. W. Livingston — B. F. Tellkamp

Working Groups:

(2-1). Electronic Control of D-C Motors

J. W. Picking, *chairman* — William Few
H. B. Black — F. G. Logan
C. J. Collom — W. G. Roman
Ben Cooper — H. I. Stanback
W. H. Elliot — B. B. Stuart
B. F. Tellkamp

(2-2). Photoelectric Pickup Systems

L. U. C. Kelling, *chairman* — F. T. Bailey

(2-3). Electronic Relaying Devices

E. B. McDowell, *chairman* — C. A. Schurr
K. P. Puchlowski — B. F. Tellkamp

(2-4). Electronic Regulators and Regulating Systems

O. W. Livingston, *chairman* — W. H. Elliot
H. B. Black — William Few
S. L. Burgwin — F. G. Logan
E. T. Davis — J. W. Picking
W. W. Snyder

(2-5). Electronic Control of A-C Power

E. W. Hutton, *chairman* — F. G. Logan
H. B. Black — W. G. Roman
W. H. Elliot — B. F. Tellkamp

3. Standards Subcommittee

Scope: This subcommittee will prepare proposals for revised and new Standards pertaining to industrial control in which AIEE is interested, especially AIEE Standard 15 which is also ASA Standard C19.1. Such proposals are in preparation to action taken by official AIEE members on the respective ASA committees. The work of co-ordinating is carried on by the subcommittee chairman who assembles working groups from time to time as the need for action on existing or new Standards arises.

G. W. Heumann, *chairman*

4. Test Codes Subcommittee

Scope: The proposed test code should contain recommendations for test procedure and test methods, as applied to industrial control equipment. The test methods recommended should be such that the tests made at different times and by different laboratories will be comparable and significant. It is desirable that the test procedures be such that the results of the tests may be interpreted and expressed in some defined scale of comparison, but it is not the purpose of the test code to set standards of acceptability. Neither should the test code attempt to determine or specify what type of investigation need be made on any given type of apparatus. It is the consensus of opinion that the efforts of the subcommittee should be concentrated on the more fundamental tests relating to basic design rather than on routine production tests.

C. T. Evans, *chairman* — H. E. Nason
D. K. Frost — W. E. Pakala
B. W. Jones — H. E. Ryan
C. A. Schaefer

Industrial Power Systems Committee

1. Interior Wiring Design for Commercial Buildings Subcommittee

Scope: To prepare and maintain a recommended guide for interior wiring of commercial buildings which will point out the best engineering practice and the reasons therefor in the interior wiring systems of this type of building. An interim report already has been prepared and the subcommittee is in the process of enlarging and revising it, to meet the universal need for a recommended practice (not a standard or code) by consulting engineers, architects, and building designers.

B. F. Thomas, Jr., *chairman* — Ralph C. Hodges
L. W. McCullough, *secretary* — R. H. Kaufmann
F. R. Benedict — George K. Perley
C. D. Bratiotis — L. C. Peterman
Leo H. Cleary — H. F. Richardson
Allan Coggeshall — C. W. Schemm
W. T. Crosman — C. F. Scott
R. F. Davis — B. Z. Segall
H. W. Dexter, Jr. — Herbert Speight
V. E. Dodson — Howard R. Stevenson
C. F. Hedlund — T. O. Sweatt
James A. Hefternan — W. Weinerth

2. Revision of Electric Power Distribution for Industrial Plants Subcommittee

Scope: This subcommittee is to review the AIEE publication on electric power distribution for industrial plants and to gather any new information preparatory to reprinting this valuable bulletin.

S. F. French, *chairman* — L. E. Fisher
J. A. Arberry — C. R. Johnson
G. E. Baker — N. B. Lainge
H. G. Barnett — S. W. Luther
E. T. Carlson — R. B. McKinley
R. F. Davis — J. J. Orr
Wm. Deans — J. S. Parsons
D. D. Douglass — R. C. R. Schulze
H. J. Finison — E. E. Turkington
R. J. Wiseman

3. Transformer Voltage Ratios Subcommittee

Scope: To maintain contact with various industry standardization groups now working on system voltages and transformer voltage ratios. This subcommittee will carry on the work of a previous subcommittee which prepared and presented the report on industrial voltage requirements.

C. C. Whipple, *chairman* — S. F. French
H. G. Barnett — J. Grotzinger
D. L. Beeman — K. Pinder
T. O. Sweatt

Communication and Science Subcommittees

Basic Sciences Committee

1. Applied Mathematics Subcommittee

Scope: To furnish needed co-operation between mathematicians and engineers, preferably by bringing specific engineering problems to the attention of mathematicians for solution rather than to consider only general problems which might be discussed from an abstract viewpoint. Members of the American Mathematical Society are invited to join with this subcommittee in mutually advantageous conferences and sessions.

M. G. Malti, *chairman* — Henry B. Hansteen
Harry Sohor

2. Electric Circuit Theory Subcommittee

Scope: Considerable work in circuit theory has been done, particularly as a result of the war effort. The function of this subcommittee is to make a thorough review of recent circuit theory developments in all fields directed toward the publication of this material and also to study circuit theory definitions which are needed urgently in view of the almost complete lack of standard circuit theory definitions existing at the present time.

J. G. Brainerd, *chairman* — F. J. Maginniss
R. L. Dietzold — W. O. Osbon
E. A. Guillemin — E. B. Payne
T. J. Higgins — W. E. Phillips
E. Weber

3. Energy Sources Subcommittee

Scope: The great impetus given to new methods of supplying electric power by developments in nuclear energy has suggested that all known methods of producing electric power should be reviewed in the light of present-day knowledge. This subcommittee is conducting conferences to review the various known means of electric energy generation, efforts being made to prepare for publication papers by outstanding experts in their respective fields.

W. A. Lewis, *chairman* — L. W. Matsch
W. C. Brown — Walther Richter
M. A. Gartens — J. J. Smith
C. R. Hanna — B. R. Teare
J. D. Tebo

4. Large Scale Computing Devices Subcommittee

Scope: The treatment of all matters in which the dominant factors are the requirements, design, construction, selection, installation, and operation of machinery and devices relating to computing devices, including studies of the electromagnetic, electronic, and mechanical phenomena of such devices. Fundamental mathematic, electronic, and properties of materials entering into these devices are not included.

C. Concordia, *chairman* — W. C. Johnson
J. G. Brainerd — G. D. McCann
S. H. Caldwell — J. C. McPherson
E. L. Harder — J. D. Tebo

5. Electrical Properties of Solids Subcommittee

Scope: Treatment of the theories explaining the electrical properties of various types of solid materials commonly used in electrical engineering, such as thermionic emission, semiconductors, dielectrics, and magnetism.

Joseph A. Becker, *chairman*
(Personnel not yet completed)

Communication Committee

1. Co-ordinating Committee

Scope: To act as liaison between the technical program committee and the working units of the communication committee.

J. L. Callahan, *chairman* — H. I. Romnes, *secretary*
R. E. Smith, *vice-chairman* — J. J. Pilliod, *junior past chairman*

Subcommittee chairmen:

H. A. Affel — F. E. Norris
J. D. Booth — E. G. Ports
G. H. Gray — F. M. Rives
H. H. Haglund — R. E. Shelby
S. C. Spielman

2. Communications Standards Subcommittee

G. H. Gray, *chairman*

3. Communication Switching Systems Subcommittee

Scope: This subcommittee would include telephone switching systems, such as crossbar, Stromberg-Carlson *X-Y* system and automatic electric director, and telegraph switching systems, such as those used for *TWX*, as well as the systems used by the telegraph companies in switching message traffic.

F. E. Norris, *chairman* — D. G. Geiger
A. J. Busch — G. H. Gray
C. H. Cramer — L. C. Holmes
H. R. Fritz — J. O. Shepherd
Arthur Bessey Smith

4. Wire Communication Systems Subcommittee

Scope: This subcommittee would cover wire line transmission systems of all kinds such as coaxial cable systems, carrier systems for telephone or telegraph, ocean cables, loading coil for cables, and regenerative repeaters for telegraph.

H. A. Affel, *chairman* — G. H. Gray
W. M. Allen — G. B. Ransom
C. H. Cramer — A. L. Rumney
H. E. Ellithorn — Arthur Bessey Smith

5. Home Radio Receivers Subcommittee

Scope: This subcommittee would handle activities related to amplitude modulation, frequency modulation, and television receivers used for the reception from radiobroadcasting stations.

S. C. Spielman, *chairman* — P. C. Goldmark
J. D. Booth — T. T. Goldsmith, Jr.
J. B. Coleman — W. A. Ready
L. G. Cumming — David B. Smith
J. C. Gaudio — William Comings White

6. Power Line Carrier Systems Subcommittee

Scope: This subcommittee would join with the power group in handling all activities related to the use of carrier currents by power companies in their operations.

F. M. Rives, *chairman* — W. D. Hailes
J. D. Booth — G. R. Messmer
W. T. Smith

7. Radiobroadcasting Systems Subcommittee

Scope: This subcommittee would cover amplitude modulation, frequency modulation, and television broadcasting stations, studio equipment, television cameras, studio-transmitter links, and anything else related to the broadcasting of programs for entertainment or instruction.

R. E. Shelby, *chairman* — T. T. Goldsmith, Jr.
Arthur L. Albert — J. V. L. Hogan
G. M. K. Baker — E. M. Johnson
J. B. Coleman — J. L. Middlebrooks
P. C. Goldmark — William Comings White

8. Radio Communication Systems Subcommittee

Scope: This subcommittee would cover radio communication systems of all kinds such as microwave relay systems for telephone, television or telegraph; mobile systems for automobiles, ships, or airplanes; and point-to-point systems for telephone or telegraph.

E. G. Ports, *chairman* — G. R. Messmer
G. T. Royden, *vice-chairman* — Haraden Pratt
E. D. Becken — R. H. Ranger
E. M. Boone — John B. Russell
I. F. Byrnes — J. Ernest Smith
T. T. Goldsmith, Jr. — William Comings White

9. Record Communications Subcommittee

Scope: This subcommittee would handle facsimile, telephoto, magnetic recording, teletypewriters, and other similar communications involving the making of a record.

H. H. Haglund, *chairman* — L. C. Holmes
G. M. K. Baker — R. R. O'Connor
E. D. Becken — R. H. Ranger
G. H. Gray — Arthur Bessey Smith
J. V. L. Hogan — R. B. Vaile, Jr.

10. Special Communication Applications Subcommittee

Scope: This subcommittee would handle miscellaneous activities which do not fall within the sope of the other committees such as hearing aids, radar, and sonar.

J. D. Booth, *chairman* — L. C. Holmes
I. F. Byrnes — L. G. Pacent
J. B. Coleman — W. A. Ready
Melville Eastham — R. B. Vaile, Jr.
W. D. Hailes — William Comings White

Electronics Committee

1. Electronic Aids to Navigation Subcommittee

Scope: The formulation of definitions of radio and electronic navigational terms. This work is being coordinated with the radio technical commission for aeronautics. In future months it is expected that the committee will undertake to formulate standards of testing various radio and electrical navigation systems.

D. G. Fink, *chairman* — E. J. Isbister
C. R. Banks — William Jackson
P. A. D'Orio — Howard K. Morgan
F. C. Dyer — Marcus O'Day
Robert C. Ferrar — George H. Phelps
N. L. Harvey — John A. Rankin
A. B. Hunt — B. Thompson

2. Electronic Precipitation Subcommittee

Scope:

1. Electrical precipitation of dust, both in air conditioning and in the removal of high concentrations of dust fume and smoke which generally has been called Cottrell precipitation.
2. Electrostatic painting and "detearing."
3. Electrostatic separation of solids.
4. Electrostatic application of abrasives and other substances in manufacturing processes.
5. Static problems in industry.

G. W. Penney, *chairman* — S. R. Orem, Jr.
J. O. Amstuz — W. F. Strong
Emery Miller — E. R. Thomas

3. Electronic Papers, Solicitations, and Section Contacts Subcommittee

Scope: Encourages and initiates the preparation of papers on any phase of electronics.

W. C. White, *chairman* — S. B. Ingram
G. M. K. Baker — L. A Kilgore
W. R. Clark — H. L. Palmer
Rudolf Feldt — J. C. Strasbourger
A. P. Godabo — Dayton Ultrey
H. Winograd

4. High-Frequency Conductors, Cables, and Connectors Subcommittee

Scope: The subcommittee has under consideration possible standardization, procurement of technical papers, and liaison work with other technical sections in connection with high-frequency cables, conductors, and connectors. The scope of this subcommittee also will include wave guides. The subcommittee has been actively considering coaxial cables, other high-frequency wires and connectors, and test methods.

G. J. Crowdes, *chairman* — B. A. Jackson
L. A. Bondon — Glenn Koger
W. R. Dohan — L. M. Leeds
E. W. Greenfield — H. B. Slade
J. W. E. Griemsmann — W. R. Thurston
J. D. Heibel — C. A. Webber

5. Hot-Cathode Electronic Power Converters Subcommittee

Scope: Preparation of standards that apply to the following types of converters: rectifiers utilizing hot cathode gas or vacuum tubes and inverters utilizing hot cathode gas tubes. This scope excludes applications in oscillator circuits and radio receivers.

E. V. DeBlieux *Chairman* — E. J. Rathsack
H. R. Butler — F. M. Rives
F. W. Cramer — W. C. Rudd
C. E. Hamann — I. R. Smith
J. F. Harris — H. C. Steiner
C. W. Hutton — H. L. Thorson
F. G. Logan — D. E. Trucksess
D. E. Marshall — J. C. Walter

6. Subcommittee for Liaison with IRE

R. S. Burnap, *chairman*

7. Subcommittee for Liaison with JETEC (Joint Electron Tube Engineering Council)

O. W. Pike, *chairman*

8. Nomenclature and Definitions Subcommittee

R. S. Burnap, *chairman*

9. West Coast Subcommittee

W. H. Pickering, *chairman*

10. Subcommittee on Electronic Developments Abroad

Scope:

1. To secure all possible data as to foreign developments in electronics.
2. To secure co-operation from foreign sources, and to assist in the procurement of these data.
3. To provide the membership of the AIEE with a concise review of the developments and trends abroad.

J. T. Thwaites, *chairman*

11. Electronic Education Subcommittee

F. N. Tompkins, *chairman*

12. Electronic Aids to Medicine Subcommittee

Scope: This subcommittee will attempt to co-ordinate medical and engineering development, acquainting the engineering profession with medical problems requiring engineering development, and acquainting the medical profession with possibilities in solution of their problems. A 2-day conference in New York is planned for the fall of 1948 with a tentative program as follows: discussions on such topics as biological requirements in amplifiers; present practice in biological amplifier design; biological requirements in recording devices including cathode-ray oscillograph, electrocardiograph, and electroencophalograph; present practice in biological recorder design; biological requirements on instruments for radioactivity measurements; present practice in biological radioactivity measurement; health and protection instrumentation; biological requirements in instruments for stable isotope measurements; and present practice in biological stable isotope instrumentation.

Doctor W. A. Geohegan, *chairman* — John P. Hervey
Doctor G. W. Dunlap — J. B. Russell
Doctor Harry Grundfest — Doctor Cornelius A. Tobias

13. X-Ray Tubes Subcommittee

Scope: Matters pertaining to X-ray tubes, rectifier tubes used in X-ray high-voltage generators, and other electron tubes used in X-ray apparatus and accessories. It contemplates work on such projects as standardizing the method of specifying the ratings and characteristics of X-ray and rectifier tubes; standardizing the symbols and form of presenting the wiring diagrams for X-ray generators; and standardizing the method of specifying the characteristics and ratings of X-ray transformers and generators.

Scott W. Smith, *chairman* — A. Klinckmann
Z. J. Atlee — J. Lempert
James M. Constable — T. H. Rogers
E. R. Goldfield — David Susin
Robert F. Wilson

14. Electron Tubes Subcommittee

Scope: Treatment of all technical matters relating to the design, construction, test, and operation of electron tubes for industrial use. The committee is starting the preparation of standards. These standards will include sections on high vacuum tubes, cathode-ray tubes, gas-filled thermionic and cold cathode tubes, phototubes, and mercury-pool cathode tubes. All pertinent information such as definitions, standards, test codes, and application practice codes that is necessary to define electron tubes technically is to be included.

H. C. Steiner, *chairman* — T. A Elder
C. H. Willis, *counselor* — A. M. Glover
W. C. White, *counselor* — R. E. Graham
T. Spooner, *counselor* — L. B. Headrick
A. Y. Bentley — O. W. Livingston
F. W. Cramer — D. E. Marshall
H. J. Dailey — H. L. Thorson
D. V. Edwards — G. T. Waugh
H. Winograd

Working Groups:

(*14-1*). High Vacuum Tubes

O. W. Livingston, *chairman* — T. A. Elder
R. J. Dailey — R. E. Graham

(*14-2*). Cathode-Ray Tubes

A. Y. Bentley, *chairman* — L. B. Headrick
G. T. Waugh

(*14-3*). Gas-Filled Thermionic and Cold Cathode Tubes—Phototubes

H. L. Thorson, *chairman* — A. M. Glover
D. V. Edwards — O. W. Livingston
D. E. Marshall

(*14-4*). Mercury-Pool Cathode Tubes

D. E. Marshall, *chairman* — A. M. Glover
F. W. Cramer — H. C. Steiner
H. Winograd

Liaison Representatives:

D. E. Marshall—subcommittee on rectifying devices of the electronic power converter committee
H. L. Thorson—subcommittee on hot-cathode electronic power converters of the electronics committee

15. Electronic Standards Subcommittee

Scope: It is the function of this subcommittee to assist the various electronic subcommittees in co-ordinating their standardizing efforts and to get them into the proper form and channels, if they are to become AIEE or American Standards. A part of this subcommittee's function is educational, in that it is attempting to show how standardization is accomplished, what national societies and associations are concerned, and how their activities are correlated.

Thomas Spooner, *chairman*

Instruments and Measurements Committee

1. Definitions Subcommittee

C. L. Dawes, *chairman* — A. J. Grant
Arthur B. Craig — Everett S. Lee
H. C. Dickinson — B. E. Lenehan
W. N. Goodwin, Jr. — P. MacGahan
F. B. Silsbee

2. Dielectric Measurements in the Field Subcommittee

F. C. Doble, *chairman* — W. N. Eddy
A. L. Brownlee — I. W. Gross
C. T. Burke — Everett S. Lee
E. B. Curdts — W. N. Lindblad
Chester L. Dawes — G. M. L. Sommerman
E. D. Doyle — L. Wetherill

3. High-Frequency Measurements Subcommittee

F. J. Gaffney, *chairman* — G. B. Hoadley
H. H. Brauer — H. Lyons
I. G. Easton — H. E. Webber

4. Marking of Varmeters and Related Instruments Subcommittee

Arthur B. Craig, *chairman* — Walter G. Knickerbocker
A. L. Brownlee — A. E. Knowlton
A. L. Carvill — L. M. Limpus
F. B. Silsbee

5. Master Test Code for Resistance Measurements Subcommittee

F. B. Silsbee, *chairman* — E. D. Doyle
C. T. Burke — Everett S. Lee

6. Master Test Code for Temperature Measurements Subcommittee

L. A. Burckmyer, Jr., *chairman* — W. R. Hough
P. A. Borden — A. K. Joecks
E. D. Doyle — M. D. Ross
J. L. Fuller — S. S. Stack

7. Subcommittee on Revision of AIEE Standard 4 (Measurement of Test Voltage in Dielectric Tests)

J. T. Lusignan, *chairman* — W. B. Kouwenhoven
A. L. Brownlee — R. S. Lapp
J. S. Carroll — W. W. Lewis
J. J. Clark — E. A. Piepho
J. E. Clem — W. C. Sealey
E. W. Davis — F. B. Silsbee
C. M. Foust — W. T. Smith
H. A. Frey — R. W. Sorensen
I. W. Gross — W. L. Teague
J. H. Hagenguth — S. W. Zimmerman

8. Subcommittee on Revision of C 39 (Electrical Indicating Instruments)

H. C. Koenig, *chairman* — J. H. Miller
C. T. Burke — A. R. Rutter
R. D. Hickok, Sr. — C. F. Savage
E. S. Lee — F. B. Silsbee
P. MacGahan — C. J. Zeller

9. Watt-hour Meters Subcommittee

W. G. Knickerbocker, *chairman* — W. N. Lindblad
A. L. Brownlee — G. A. Palmer
D. T. Canfield — G. B. M. Robertson (AEIC) *ex officio*
A. B. Craig — A. R. Rutter
F. C. Holtz — C. F. Savage
H. C. Koenig — M. B. Stout

General Application Group Subcommittees

Air Transportation Committee

1. Aircraft Electric Rotating Machinery Subcommittee

Scope: This subcommittee was organized in 1944 for the purpose of preparing standard test codes for aircraft electric rotating machinery. As a result, AIEE 800, Proposed Test Code for D-C Aircraft Machines, was published in March 1947 for one year trial use. The subcommittee now is preparing "Rating Standards for Engine-Driven Generators."

D. E. Fritz, *chairman* — R. D. Jones
J. W. Allen — L. R. Larson
A. Fisher — A. N. Lawrence
S. H. Hanville, Jr. — G. W. Sherman
R. R. Smith

2. Aircraft Systems Subcommittee

Scope: The purpose of this subcommittee is to formulate a report on the basic and accepted considerations involved in the application practice of aircraft electrical systems. This report shall contain information of the following character: an explanation of fundamental electrical problems, outlines of systematic procedures for analysis and computation of aircraft electrical system performance, and formulation of general application practices which will assure correct coordination of equipment.

W. F. Moore, *chairman* — G. A. Phillips
J. W. Allen — D. H. Scott
H. B. Bunce — K. R. Smythe
H. L. Hildebrandt — A. J. Snyder
A. F. Trumbull

3. Subcommittee on Basic Principles of Altitude Rating of Electric Apparatus

Scope: This subcommittee will prepare no test codes nor standards for specific apparatus; but rather, it will prepare a report indicating the basic principles of altitude rating of electric apparatus. Such a report will be useful in the preparation of test codes and standards and in the design and testing of aircraft equipment. The first phase of the project will be from sea level to 50,000 feet altitude.

W. E. Pakala, *chairman* — J. G. Hutton
J. W. Allen — Chester A. Maple
T. R. Brown — A. T. McClinton
S. H. Hanville, Jr. — R. A. Rugge

4. Subcommittee on Aircraft Electrical Control, Protective Devices, and Cable

Scope: Formation of test codes and operating standards for aircraft electrical control, protective devices, and cable. The subcommittee is engaged presently in the preparation of a test code for aircraft circuit interrupting devices and a test code for aircraft d-c generator voltage regulators is being prepared by a working group of the subcommittee.

R. J. Lusk, *chairman* — H. S. Moore
B. O. Austin — W. F. Moore
E. E. Magee — J. Ottmar
A. T. McClinton — J. H. Taylor
R. A. Millermaster — W. W. West

Land Transportation Committee

1. Heavy Traction Electrification Data Subcommittee

Scope: To collect and tabulate data covering power supply, conversion and distribution systems, and motive power of electrified railroads in the United States and to present them in a way to show the extent of existing electrifications and trends as indicated by chronological developments. Since 1933, general information on railway electrification, both domestic and foreign, has not been available principally because of the discontinuance of the collection of these data by the National Electric Light Association and the disbanding of the heavy electric traction committee of the American Transit Association. In January 1947, this subcommittee was formed and the work is divided into five projects.

L. W. Birch, *chairman* — W. J. Clardy
H. F. Brown — F. H. Craton
A. G. Oehler

Projects:
(*1-1*). Catenary overhead systems
(*1-2*). Third rail systems
(*1-3*). Electric locomotives
(*1-4*). Substations
(*1-5*). Power supply

The personnel of the projects is as follows:
(*1-1*) and (*1-2*). L. W. Birch, *chairman*; H. F. Brown
(*1-3*), (*1-4*), and (*1-5*). A. G. Oehler, F. H. Craton, W. J. Clardy

2. Heavy Traction Papers and Plans Subcommittee

Scope: To secure papers and discussion for the various AIEE meetings, covering matters of current interest in the field relating to railroad electrification, Diesel-electric locomotives, and all other applications of electricity to railroad rolling stock such as lighting and air conditioning of passenger cars. This is accomplished by correspondence and personal contact with the leading manufacturers of equipment, and the engineering personnel of the major electrified railroads and consulting engineering firms engaged in such projects.

H. F. Brown, *chairman* — A. L. Brecht
R. L. Kimball

3. Light Traction Papers and Plans Subcommittee

Scope: To secure papers and discussion for the various AIEE meetings, covering matters of current interest in the field relating to local transit, that is, subway, streetcar, and trolley coach systems, and applications of electric propulsion equipment to internally powered local transit vehicles.

W. J. Clardy, *chairman* — Harold R. Blomquist
Dwight L. Smith

4. Subcommittee on Revision of AIEE Standard 16 (Electric Railway Control Apparatus) ASA C48 Subcommittee

Scope: To revise AIEE Standard 16 (Electric Railway Control Apparatus) for the purpose of recognizing new processes, correction of errors, and inclusion of certain new functions and devices. These Standards last were revised in 1933. The subcommittee reported at the Montreal meeting June 1947 and is expecting to present a final report soon.

F. H. Craton, *chairman* — W. S. H. Hamilton
W. J. Clardy — J. G. Inglis

Marine Transportation Committee

1. Power Generation Subcommittee

C. Lynn, *chairman* — L. M. Goldsmith
W. B. Armstrong — R. G. Lorraine
R. A. Beekman — Edward H. Stivender
H. C. Coleman — Oscar A. Wilde

2. Power Application Subcommittee

L. M. Goldsmith, *chairman* — Joseph B. Feder
H. C. Coleman — Jesse E. Jones
R. W. Erickson — R. G. Lorraine
William H. Reed

3. Wires and Cables Subcommittee

W. N. Zippler, *chairman* — A. R. Gatewood
Edgar C. Alger — R. G. Lorraine
Joseph B. Feder — Vernon W. Mayer

4. Switchboards and Control Subcommittee

H. C. Coleman, *chairman* — H. Franklin Harvey, Jr.
W. B. Armstrong — Jesse E. Jones
R. A. Beekman — Vernon W. Mayer
P. J. DuMont — Edward H. Stivender

5. Distribution Subcommittee

H. F. Harvey, Jr., *chairman* — J. B. Feder
Edgar C. Alger — A. R. Gatewood
P. J. DuMont — P. A. Guise
R. W. Erickson — F. A. Wickel
W. N. Zippler

6. Fittings and Appliances Subcommittee

O. A. Wilde, *chairman* — Vernon W. Mayer
P. J. DuMont — Samuel N. Mead
A. R. Gatewood — Wm. H. Reed
P. A. Guise — Edward M. Rothen
H. Franklin Harvey, Jr. — F. A. Wickel

7. Communications and Alarm Subcommittee

Edgar C. Alger, *chairman* — S. M. Mead
J. B. Feder — E. M. Rothen
V. W. Mayer — Carlton W. Souder
F. A. Wickel

8. Navigation Equipment Subcommittee

Samuel N. Mead, *chairman* — P. A. Guise
P. J. DuMont — E. M. Rothen
Carlton W. Souder

9. Publicity, Personnel, and History Subcommittee

R. A. Beekman, *chairman* — H. F. Harvey, Jr.
William H. Reed

10. Editing Subcommittee

W. N. Zippler, *chairman* — H. F. Harvey, Jr.
William H. Reed

Production and Application of Light Committee

1. Ultraviolet Radiations Subcommittee

Scope: The initial scope will be to sponsor the preparation of a report on modern ultraviolet sources. The group also would serve as a clearing house for all information relating to its specific field, and will help in planning convention papers and securing speakers on this subject.

Allen J. Dussault, *chairman*

2. Nomenclature of Electronic Lamps Subcommittee

Scope: This subcommittee was formed for the purpose of co-operating with the subcommittee on electronic standards of the committee on electronics in the preparation of a system of definitions of electronic devices used as light sources. In this connection, light sources is taken as including sources of infrared, visible, and ultraviolet radiations.

E. H. Salter, *chairman* — L. R. Keifler
E. W. Beggs — R. C. Putnam
T. C. Sargent

OF CURRENT INTEREST

Experimental Advances Discussed at Electron Microscope Conference

More than 50 scientific papers on new techniques, and new advances in the electron microscope itself, were reported December 11–13, 1947, at the first international conference of the Electron Microscope Society of America which was held in Philadelphia, Pa. Leading electron microscope research specialists from England, France, Holland, India, Australia, and Canada, as well as many parts of the United States, were among the 250 scientists attending the sessions. Some of the subjects of interest to electrical engineers are reviewed briefly in the following paragraphs.

Technical advances reported at the conference included experimental development of a new "double lens," increasing the light contrast in photographs made with the RCA electron microscope, and a new light optical viewer providing increased magnification for direct observation of electron microscope images, both described in a paper by Doctor James Hillier and S. G. Ellis, of the RCA Laboratories, Radio Corporation of America. Pictures obtained with the new lens, showing a tiny virus entering and killing a living cell, were hailed as a milestone in medicine and biology, pointing to a new approach in the war of science on such mass murderers as polio and cancer.

ELECTRON DIFFRACTION CAMERA

A new electron diffraction camera, using a beam of electrons only a fraction of the diameter of human hair to "thumbprint" minute specimens of crystalline substances and reveal the arrangement of atoms in their molecules, was announced in a paper by Perry C. Smith and Robert G. Picard, both of whom are with the scientific instruments section of the RCA engineering products development.

A new portable vacuum leak detector that "sniffs" out leaks so small that molecules of air have trouble squeezing through them was demonstrated for the first time by Herbert Nelson, of the RCA tube department. The device is designed for use in laboratories and factories to locate leaks that otherwise might destroy the vacuum in such devices as electron tubes, X-ray tubes, electron microscopes, cyclotrons, and vacuum stills.

3-DIMENSIONAL EFFECTS

Use of uranium sulfide or platinum as a "shadow-casting" material to obtain 3-dimensional effects in electron micrographs of viruses and other tiny particles was described by Doctor Robley C. Williams, and Robert C. Backus, of the University of Michigan, who found these materials superior to gold, which formerly was used for this purpose, as they are free from the tendency to granulate when subjected to the electron beam in the microscope. By vaporizing bits of these materials in a vacuum, a microscopically-thin film is formed on all portions of the specimen except where upright details block the flying atoms, in effect casting shadow such as a tree would cast by blocking sunlight. When the specimen is viewed in the electron microscope, the "shadows" indicate the depth and character of surface details. By highlighting such details, they said, this technique also makes it possible to use much greater magnifications than otherwise would be practicable.

SHORTAGE OF MICROSCOPISTS

An entire afternoon session of the conference was devoted to a symposium on the problem presented by a rapidly developing shortage of electron microscopists. There are approximately 300 electron microscopes in use in hospitals, scientific laboratories, universities, and industry at this time. It was pointed out that with only about 600 research specialists trained in this field and all of them engaged in the work now in progress, there is no reservoir on which to draw as the field expands.

Speakers at the symposium urged that educational institutions recognize electron microscopy as a field of scientific specialization for which a formal, permanent program of training is needed. A spokesman for the Massachusetts Institute of Technology indicated that the first such program at an undergraduate level will be inaugurated in that institution next year.

Harvy B. Merrill, of Custom Scientific Instruments, Arlington, N. J., and Ernest F. Fullam, of the General Electric Company, demonstrated a new "ultramicrotome" developed by the former concern. The device, designed to cut sections of industrial and biological materials only four millionths of an inch thick for study in the electron microscope, whirls a razor-edged blade at the speed of 800 miles an hour on a drum rotating at 60,000 revolutions per minute.

OFFICERS ELECTED

Perry C. Smith of the scientific instruments section of the RCA engineering products department, Radio Corporation of America, was named president of the society at the annual election. Other new officers are Doctor Francis O. Schmitt, of Massachusetts Institute of Technology, president-elect; Doctor C. J. Burton, of American Cyanamid Corporation, secretary; Mrs. Mary Jaffe, of General Electric Company, treasurer; and M. Charles Banca, of the RCA scientific instruments section, Radio Corporation of America, and Doctor William G. Kinsinger, of Hercules Powder Company, directors.

Letter Sent to President on EJC Science Legislation

The following is a letter sent by the Engineers Joint Council to President Truman on the subject of science research legislation. The letter is signed by the presidents of the five constituent societies of EJC.

The President
The White House
Washington, D. C.

Dear Mr. President:

The undersigned presidents of the major engineering societies of the United States respectfully submit that the establishment of a National Science Foundation is a matter of vital national urgency which can not suffer further delay. We are cognizant of the differences in views which have marked the consideration and have delayed the enactment of science legislation. Despite these differences, we believe there is substantial agreement on the objectives of the National Science Foundation and on the principles essential to successful organization and administration.

The need to establish the foundation according to sound principles of government is recognized. Involved in consideration of the form of the organization, however, is the need to command and retain the confidence and support of scientists and qualified laymen by giving them an effective, responsible place in the Foundation's affairs. We believe this can be achieved to your satisfaction and theirs. We, therefore, respectfully express the hope that you may see your way to assume the initiative in causing competent consideration of science legislation by a small group representing yourself, congress, and the scientists for the purpose of coming to agreement on legislation which could be acted on and put into effect soon after the first of the year.

E. M. HASTINGS
(president, American Society of Civil Engineers)

CLYDE E. WILLIAMS
(president, American Institute of Mining and Metallurgical Engineers)

E. W. O'BRIEN
(president, American Society of Mechanical Engineers)

B. D. HULL
(president, American Institute of Electrical Engineers)

CHARLES M. A. STINE
(president, American Institute of Chemical Engineers)

Shawinigan Announces Trenche Development Details

Pursuant to the recent announcement by the Provincial Government of new hydroelectric developments to be constructed in the Province of Quebec, Canada, The Shawinigan Water and Power Company has announced the following particu-

lars regarding its 384,000-horsepower Trenche development on the upper St. Maurice River.

The location of the new plant is 25 river miles upstream from the town of La Tuque and five river miles below the Shawinigan Company's 200,000-horsepower development at Rapide Blanc. The plant will operate at a head of 160 feet, the highest of any of the Shawinigan developments on the St. Maurice River. When completed, it will have an ultimate capacity of 384,000 horsepower, comprising six units of 64,000 horsepower each, of which five will be installed immediately. Next to Shawinigan Falls, this will be the largest development on the St. Maurice River, and, with the installation of the five units, the total installed capacity of the river will amount to 1,605,400 horsepower.

Actual construction work is scheduled to start in May 1948, and among the first tasks to be undertaken will be the construction of a road, connecting the Rapide Blanc road, which was constructed by the Company in 1930, with the site of the new development. The first delivery of power is planned for the fall of 1951 and the five units will be brought into production successively from that time.

It is expected that there will be a ready market for the entire output of the plant in view of present demand and prospective increases in the load of the Shawinigan system. During 1948, there will be 1,000 men employed on the project, and in the course of the construction work over the following three years, employment will reach a peak of around 3,000 men. The total payroll will amount to around $9,000,000. The over-all cost of the development, including a new 110-mile 220,000-volt transmission line from the plant to the Company's Terminal Station at Trois Rivieres, will be in the neighborhood of $35,000,000. A very considerable portion of the materials and equipment required both for the power development and the transmission line, will be purchased in the Province of Quebec.

Conference on Illumination to Meet in Paris, July 1–7

The following information regarding the forthcoming international conference on illumination has been received:

Gentlemen:

It is desired to call attention of AIEE members to the first international conference on lighting to be held since the war. The International Commission on Illumination is scheduled to meet in Paris, July 1–7, 1948.

Interestingly enough this meeting follows a meeting of the International Conference on Large High-Tension Systems (CIGRE) which is being held in Paris June 24 to July 3. Those attending the CIGRE meeting who desire to attend the ICI conference, may secure the necessary information from Arthur A. Brainerd, Secretary, United States National Committee, Philadelphia Electric Company, Philadelphia, Pa.

Some 100 Americans are at work preparing material to be included in the reports of 25 technical committees dealing with various aspects of light sources and illumination. Secretariats for these several subjects are distributed among various countries, the following being located in the United States:

Colorimetry and artificial daylight
Lighting of public ways
Lighting practice
Cinema screen and cinema auditorium lighting

The AIEE is represented on the United States National Committee of the ICI by:

S. G. Hibben (M '45)
Ward Harrison (F '36)
Harris Reinhardt (M '42)

Nine years will have elapsed since the previous ICI conference which was held in Holland in 1939, just preceding the outbreak of the war. In the interval almost all of the technique of fluorescent lighting application has taken place and many other developments and trends have occured on both sides of the Atlantic.

Partly for this reason and partly because the United States having been less affected physically by the war has more to share with European countries, this year's conference is expected to be of greater importance than almost any in the past.

Sharing of food and materials through the good offices of our national government is more or less impersonal but sharing of knowledge which will enable those less fortunate than ourselves to bridge the gap of lost years and immediately to go forward on the basis of the most modern practices is not something that can be done for one by any impersonal group.

For that reason any member of the AIEE who is concerned with lighting and who can contribute to the deliberations of the forthcoming international sessions will be welcome as a delegate to the Paris meeting.

PRESTON S. MILLAR (M '13)

(President, United States National Committee—ICI)

Lima Meeting Recommends Pan American Convention

Need for the organization of a Pan American Association of Engineering Societies with purposes and constitution similar to those of the Federation of South American Engineering Societies (USAI), as well as the possibility of convening a Pan American Engineering Congress, were discussed at a recent conference of representatives of the USAI held in Lima, Peru. Engineers Joint Council's committee on international relations was represented at the meeting by James S. Thompson.

A motion, in accord with one adopted by the fifth convention of the USAI in Montevideo, Uruguay, in March 1947, passed for submission to the board of directors of USAI reads as follows:

"That the participating delegates and official representatives here assembled, who are meeting in accordance with the action of the board of directors of USAI and on the initiative of the Argentine executive committee of that organization, are unanimously agreed upon the desirability of the organization of a Pan American Association of Engineering Societies and believe that a convention for this purpose should take place in the city of Bogota during the year 1948, which convention would be called under the auspices of the Board of Directors of USAI."

The Lima conference agreed that the meeting of USAI, limited to South American engineering societies, which was planned for Rio de Janeiro in 1948, should be expanded into a Pan American Engineering Congress and held during the month of March 1949.

ASA Appoints Hussey as Administrative Head

Vice Admiral George F. Hussey, Jr., United States Navy (retired), wartime chief of the Navy's Bureau of Ordnance, has joined the staff of the American Standards Association, and on January 1 assumed the duties as administrative head of that organization. In this capacity Admiral Hussey will direct the co-operative efforts of industry, consumers, and government in the vital problem of standardization. Cyril Ainsworth, who for a number of years has been in charge of the technical activities of the ASA, will serve with Vice Admiral Hussey as director of operations of the ASA staff.

Admiral Hussey started his outstanding navy career in 1912 with an appointment to the United States Naval Academy, and has served in many capacities requiring the highest order of skill and ability. Specializing in ballistics, Admiral Hussey advanced in grade and responsibility to the position of Chief of Bureau of Ordnance, Navy Department, Washington, D. C. For his service in this capacity he was awarded the Distinguished Service Medal.

In accepting the appointment, Admiral Hussey will take over the tremendously increased administrative responsibilities from Doctor P. G. Agnew, under whose capable direction the ASA has progressed to its present high level. Doctor Agnew, one of the world's foremost authorities on standardization, will continue his service to ASA as consultant.

The American Standards Association, faced with an unprecedented demand for service to industry, consumer, and government, expects to increase its activities during this year to approximately three times that of the largest year before the war. At the present time there are more than 366 projects being carried on under ASA procedures with more pending. Projects such as the standardization of womens dress sizes, business methods, and symbols for use in work on supersonic projectiles and airplanes are indicative of the wide range of subjects covered in the many requests for service.

NYU Dean on Public Health Council. Dean Thorndike Saville of New York University's college of engineering was appointed recently by Governor Thomas E. Dewey to serve on the Public Health Council until January 1, 1953, during the unexpired term of the late Henry Neely Ogden of Ithaca, N. Y. The Public Health Council is composed of eight members, each serving for a 6-year period. The council advises the commissioner of health on various matters relating to the preservation and improvement of public health, including additions and amendments to the state sanitary code. Dean Thorndike Saville has held his present post at New York University since 1936. He is a member of numerous engineering and scientific organizations including the American Society of Civil Engineers of which he is a director, the American Water Works Association, the American Society for Engineering Education, the American Institute of Consulting Engineers, the American Association for the Advancement of Science of which he is a vice-president, the Harvard Engineering Society of which he is president, the Engineers' Club of New York of which he is a member of the board of governors, the Harvard Club of New York City, Phi Beta Kappa, Sigma Xi, and Tau Beta Pi.

Welding Engineering at Ohio State. Establishment of a department of welding engineering, first of its kind in the United States, has been announced by Ohio State University. The new department will offer undergraduate work leading to the degree of bachelor of welding engineering and advanced study for graduate engineers. A pioneer in the field of welding engineering, Ohio State's college of engineering has offered a curriculum in this field for some nine years, as a division of the department of industrial engineering. Establishment of the division as a separate department was authorized by the board of trustees on the recommendation of the college of engineering and the faculty council. Curricula designed to meet the demands of industry for welding engineers will be developed in consultation with leading engineers in the nation.

JOINT ACTIVITIES

United Engineering Trustees, Inc. Issues 1946-47 Annual Report

The annual report of United Engineering Trustees, Inc., for the year ending September 30, 1947, recently was submitted to the AIEE and other participating societies.

ENGINEERING SOCIETIES BUILDING

Because of demand on the part of the Founder Societies either for more room in the Engineering Societies Building at 29–33 West 39th Street, or for a new home, the UET authorized the employment of a consulting engineer to study the situation. The conclusions of this study were that it is impractical to make material structural alterations in the existing building and that additional space will have to be provided by the purchase of an adjoining building which is not presently available. In view of lessening pressure by tenants of the Engineering Societies Building, it has been decided that for a few years to come the building can remain in status quo. Should additional space eventually be demanded, either the adjoining Haskins and Sells building must be purchased or a new headquarters found elsewhere in the city.

ASSETS

The corporation lists among its assets the cost ($1,993,793.92) of the Engineering Societies Building depreciated by a fund which, on September 30, 1947, was $621,890.19. This property is listed on the city assessment rolls at $910,000, of which the land is valued at $410,000, leaving $500,000 as the assessed value of the Engineering Societies Building. It remains exempt from taxation. The UET also has sole ownership of the principal of certain funds, the income of which is designated by deed of gift for the operation of the Engineering Societies Library and of the Engineering Foundation, the funds of the John Fritz Medal Board of Award and the Daniel Guggenheim Medal Board of Award, and is designated as treasurer and custodian of the Engineers' Council for Professional Development.

It always has been the policy of the UET, Inc., to purchase securities of the best quality and to hold until maturity, except when it is indicated that the quality of the list of investments can be improved by a change. Comparatively little buying or selling was done in the fiscal year reported.

The books of the corporation were audited twice during the year. The aggregate book value of UET capital fund investments on September 30, 1947, the close of the fiscal year, was $1,751,106.84, with a market value of $1,853,261.97, or 106 per cent of book value (the value at which the items were listed whether by purchase or gift). Corresponding value for the previous year was 105 per cent.

Annual Report Submitted by Engineering Societies Library

The annual report of the Engineering Societies Library for the year ending September 30, 1947, recently was submitted to the AIEE and other participating societies by Ralph H. Phelps, director.

The outstanding feature of the 34th Library year, 1946–47, was thorough study of the Library, made by the Committee on Library Objectives and Development, E. F. Church, Jr., chairman. The report on this study includes a statement of the objective of the Library, reports the present status of the Library, considers its future possibilities, and recommends actions to meet its needs.

The report shows that since 1941 the cost of important items in the Library budget have increased from 50 to 65 per cent, but in the same period Library income has increased only 18 per cent. It has been possible to avoid severe curtailment of Library activities only by the use of credit balances accumulated during the war years.

It lists library services and gives a table showing that the use of these, on the average, has increased 25 per cent in the last two years. This figure was based on an estimate. Final figures now show that the increase is 20 per cent. It also shows that the staff is inadequate, that salaries are too low and are not comparable to Founder Society salaries, that more space for shelving is needed, that the book and periodical collections require strengthening, and it also recommends a program of publicity and promotion to increase the usefulness of the Library.

A large amount of work went into the study and the preparation of the report, which is the most comprehensive report ever made on the Library. Whether the work will prove to have been worthwhile—whether the report will be of great or little value—is dependent on the extent of the action taken to make the recommendations effective.

Library use was five per cent greater this year than last year. Especially important is the nine per cent growth in use of the Library by nonvisitors, indicating, as it does, the widespread use of the Library. Forty per cent of Library users in 1946–47 did not visit the Library.

Careful consideration was given to the Farmington Plan, which is a comprehensive "proposal for the division of responsibility among American libraries in the acquisition and recording of library materials." By this plan at least one copy of every book or pamphlet published anywhere in the world which reasonably might be expected to have an interest to a research worker in America, is to be acquired, made available in some participating library, and listed in the Union Catalog at the Library of Congress. For the present, the plan is limited to current materials in the Latin alphabet. To be consistent, the Engineering Societies Library would have to cover at least the four fields of the Founder Societies if it undertook any. Initial cost would be about $1,000 a year, but it would increase to possibly $10,000 a year. On account of space limitations, as well as for financial reasons, the Library regretfully declined participation in this meritorious undertaking.

The Engineering Societies Monographs Committee was inactive during the war years. During the year it was reorganized again, the director of the Library acting as

chairman. It examined two manuscripts but did not approve any for publication.

As the search and translation services were operating at about a 20 per cent loss under 1940 rates, the rates were raised as follows:

Searches from $2.50 to $3 per hour.
Translations:
German, French, and so forth from $1 to $1.50 per 100 words.
Russian, Swedish, and so forth from $1.20 to $2 per 100 words.

In the case of searches, the charge is made only for the hours spent on the job, but the income must cover a large amount of preliminary correspondence and estimating. Much of this does not actually result in any paid work for the Service Bureau.

Even with the increased rates the Service Bureau does not quite "break even" on this work but there is reason to believe that it will be able to do so.

The income from photostats more than covers the loss on searches and translations.

ACQUISITIONS, CATALOGING, AND BINDING

During the year 8,081 volumes, pamphlets, maps, and the like, were received. Of these, 5,095 were added to the Library. The remainder, being duplicates or works of no value to the Library, were given to other libraries or reserved for sale or exchange as opportunity arises.

In addition to the foregoing, several thousand reports were received from the Office of Scientific Research and Development, and from the National Advisory Committee for Aeronautics. These wartime reports that have been released since the end of the war were not included in these figures, because, although the material is sorted roughly and can be used with difficulty, it is not yet cataloged.

Several hundred foreign language wartime books also have been received through the Library of Congress. For the most part these have not been added to the collection as the cataloging, which is being done by many libraries on a co-operative basis is not complete. The co-operative cataloging done by this Library on these books has been very time-consuming because of the detail which is required by the Library of Congress.

During the last four years the binding of periodicals had fallen far behind. This situation now is being corrected but will require much more work. To improve the handling of periodicals, a Kardex check file partly has been set up. This now is taking considerable time but should save time and improve service in the long run.

The total resources at the close of the year were 164,051 volumes, 10,316 maps, and 4,943 searches—a total of 179,310 items.

As in the past the Library has received many valuable gifts of books and magazines. This year there were no very unusual gifts but some of the more useful ones were those from E. C. Brown, C. W. Franklin, F. T. Sisco, A. Ekwall, and A. E. Wheeler. Many gifts of Founder Society publications were received in response to requests published in the Founder Society journals. Those covering the war years are especially useful for exchange purposes.

Various technical societies, publishers, and other organizations have given generously of their own publications and other publications that have come to them.

The Library, as always, is enriched by the gifts received, and offers sincere thanks to all donors.

FINANCE

The budget for general operation was $59,000, of which the following amounts were provided by the Founder Societies on a membership basis:

American Society of Civil Engineers	$11,269.10
American Institute of Mining and Metallurgical Engineers	8,807.30
American Society of Mechanical Engineers	10,744.10
American Institute of Electrical Engineers	12,062.00
	$42,882.50

Expenditures amounted to $51,701.55, of which $6,584.27 was spent for books, periodicals, binding, and other equipment of permanent value.

Annual Report Is Issued by the Engineering Foundation

The annual report of the Engineering Foundation for the year ending September 30, 1947, recently was submitted to the AIEE and other participating societies by A. B. Kinzel, chairman, and E. H. Colpitts (F '12), director. The Engineering Foundation is the joint research agency of the Founder Societies.

The Engineering Foundation, a department of United Engineering Trustees, was established in 1914 and thus completed its 33d fiscal year on September 30, 1947. The book value of the Foundation's capital funds at the close of the 1946–47 fiscal year was $936,623.70 as compared with $944,242.28 on September 30, 1946. The income for the past fiscal year was $33,893.85 as compared with $33,850.21 for the previous year, and the disbursements amounted to $28,971.29 as compared with $32,511.23 for the year 1945–46. The balance was $53,138.06 as compared with the 1946 balance of $48,215.50.

For the year 1946–47 grants were made in support of 13 projects. For the year 1947–48 grants are recommended to enable continuation of nine projects and for the support of eight new projects.

Summaries of the projects of the Foundation with which the AIEE directly is concerned follow.

WELDING RESEARCH COUNCIL, PROJECT 62

(Comfort A. Adams (F '13) The Budd Company, Philadelphia, Pa., chairman; H. C. Boardman, Chicago Bridge and Iron Company, Chicago, Ill., vice-chairman; W. Spraragen (M '26), New York, N. Y.)

The following concise report covering the activities of the Welding Research Council for year 1946–47 emphasizes the need for much further basic research in metallurgy particularly that relating to the flow and fracture of metals. It is clear that a better understanding of the phenomena of plastic flow, and fracture of metals is required not only for a complete explanation of the behavior of welded structures, but is required equally for others, such as riveted or bolted. The report also emphasizes the increased costs of research and indicates some tendency on the part of industry to limit financial support.

The current year has marked the completion of transition from wartime activities to a peacetime program. Fortunately, most of the projects of the Council were concerned largely with fundamentals, and these, with slight reorientation, readily were adapted to peacetime conditions.

Some of these wartime investigations developed the necessity for a deeper knowledge of the flow and fracture of metals and the behavior of welded structures in the plastic range. Two very comprehensive reviews of existing knowledge were undertaken independently: one, under the auspices of the United States Navy, and the other by the Council. At first, the Navy report was issued as a confidential document, but just has been released and made available to the Council. It was published in the August 1947 issue of the *Welding Research Supplement*. These two reports, one by Doctor John H. Hollomon, and the other by Doctor Maxwell Gensamer and associates, constitute a very excellent summary of our knowledge in this field. They also indicate the direction of most needed research. During the coming year an attempt will be made by the Council to obtain some agreement among the scientists concerned as to the most important projects and their order of importance.

During the past year the work of a very large project of the Council, which has continued over a number of years, has come to a halt, namely, the Fatigue Studies of Welded Structural Joints. The original program laid out to provide bridge engineers and code-making bodies with safe working stress date for welded structures subjected to cyclic loading, already has answered some of the important practical questions, although much is yet to be desired in the way of a more thorough understanding of the fundamental phenomena involved.

The reason for the holdup in this program is not so much the feeling that the field is by any means exhausted, but rather that present knowledge concerning the behavior of welded joints under alternating or pulsating stresses, exceeds the knowledge of the behavior of riveted joints under similar stresses.

Thus, as riveted joints still are employed

so largely for many types of steel structures, two major financial backers, namely the Association of American Railroads and the Public Roads Administration temporarily have withdrawn their financial support and have applied it to similar research work in the field of riveted construction.

This has suggested the desirability of having the Welding Research Council sponsor and participate in research work not directly involving welding. It is the chairman's conviction that as long as it can serve industry by organizing cooperative research, the Council cannot stop at any arbitrary boundary which might be assigned to welding.

On a long-term basis a very important activity of the Council continues to be the work of the University Research Committee in the stimulation and encouragement of research work among the leading universities of the United States.

Other active smaller projects include high alloys, the inter-related activities of the old Weld Stress Committee now in process of reorganization.

The most difficult job of the Council continues to be the raising of the funds necessary to keep the large programs going. This has become increasingly difficult. As a matter of fact, actual operations of the Council during the past year have been at the rate of about $200,000, rather than at the rate of $275,000 originally scheduled. Although the budget for the coming year will be of the order of one-quarter of a million dollars, in all probability actual operations will continue at the rate of about $200,000.

One of the factors contributing to the financial difficulties is the increased cost of the investigational programs at the universities. Heretofore it has been possible for the universities to operate successfully with the matter of a few hundred, or a few thousand dollars for a specific project. Costs now literally have doubled, and in some instances more nearly have trebled, for the same accomplishments. The upward cost trend is still not complete.

In spite of all this, the Welding Research Council is becoming better known all over the world. Probably no single activity contributes more to this state of affairs than the two regular publications of the Council, namely, the *Welding Research Supplement*, published monthly as the supplement to *The Welding Journal*, and made available in separate form, and the monthly mimeographed progress reports of current investigations and programs of work contemplated. This enables scientists and others to offer freely their comments and criticisms on programs before actual work is started.

The "Canons of Ethics for Engineers" have been sent to all eight of ECPD's sponsoring societies to secure the necessary assent to their formal adoption by ECPD. The Canons are the product of years of work by Doctor Dugald C. Jackson and his Committee on Principles of Engineering Ethics. Members of this committee, representing all of the supporting societies, collaborated in preparation of the final draft after considering all of alternative drafts in the wording of which many persons had spent time and effort conscientiously.

ECPD, PROJECT 56

(James W. Parker, Detroit Edison Company, Detroit, Mich., chairman; H. H. Henline (F '43) AIEE, New York, N. Y.). The Engineers' Council for Professional Development during the year operated through a number of committees as follows:

Committee on Student Selection and Guidance Carl J. Eckhardt, chairman.

Committee on Engineering Schools, D. B. Prentice, chairman.

Committee on Professional Training, Charles F. Pohl, chairman.

Committee on Professional Recognition, N. W. Dougherty, chairman.

Committee on Information, G. Ross Henninger (F '43) chairman.

Committee on Principles of Engineering Ethics, D. C. Jackson (HM '44), chairman.

The Engineering Foundation this year is contributing $4,000 toward the current operating expenses of ECPD which, with the $7,310 contributed by the sponsoring societies and a small amount from the sale of reports and pamphlets, constitutes all of the income of the Council for this year. Projects such as the preparation of the "Fifteen Year Report" are financed by special grants, usually from the eight sponsoring societies, while the accrediting of curricula in the colleges and technical institutes is substantially self-supporting. The total income of the Council from all sources in 1946–47 was $15,100.

During 1947, the Engineers' Council for Professional Development completed preparation of its "Fifteen Year Report" and now is publishing it by distribution to the governing boards of the supporting societies and their local sections, to teaching and other learned institutions, and to industrialists and many others who have supported the work of the Council and would be interested. The report is an exposition of the purposes of ECPD, an account of its accomplishments during the 15 years of existence and, even more important, a forecast of its future objectives which it is believed will awaken the interest of members of the engineering profession and their associates; and, perhaps, will evoke their support.

The Council's cosponsorship of the Measurement and Guidance Project in Engineering Education has proved of notable value in securing wide acceptance of the achievement tests being given first-year students in a large number of colleges. The particular phase of testing known as the Pre-Engineering Inventory now is looked upon as a useful tool in the hands of educators. Extension of that testing technique to the sophomore and senior years in college now is being developed and, it is believed, will be of assistance to ECPD's Committee on Engineering Schools in perfecting the methods of accrediting the engineering curricula offered by the various institutions examined.

The Measurement and Guidance Project is now about to extend the testing process to preparatory-school pupils in the tenth grade, thus placing in the hands of the ECPD Committee on Student Selection and Guidance a measuring technique which should have far-reaching effects on the means of selecting students for entrance into engineering schools and affording, eventually, criteria by which the quality of secondary schools inevitably will be judged.

The inspection of the curricula of engineering schools has been resumed actively. It is recognized that postwar enrollments, far above prewar enrollments, complicate the operation of engineering colleges and may impair the effectiveness of instruction; but at the same time, it is believed firmly that engineering education must not be allowed to go longer with the unverified endorsement of ECPD. It is hoped that all colleges presently having accredited curricula will be re-examined within the next three academic years. The accrediting of curricula in technical institutes also has been started.

A little more than a year ago, ECPD engaged the talents of the late Doctor W. E. Wickenden (F '39) in the preparation of a "Manual for Junior Engineers" for use as a guidance text to assist engineers recently graduated from college in passing successfully through the engineer-in-training years until, with experience matured, they are recognized as members of the profession. Doctor Wickenden's untimely death leaves the manuscript of the Manual practically complete, ready for rewriting and editing, on which he was already at work. The task now is the quite delicate one of engaging an author to complete the work without impairing the excellence of both style and content of the first manuscript.

The Council has given much consideration to the means by which such excellent material as this "Manual for Junior Engineers" and Doctor Wickenden's "The Second Mile" and other excellent pieces of guidance literature can be put into the hands of engineers in their postcollege years; and to the means of assisting them in some important degree in the systematic continuation of the educational process. It is quite apparent that this and indeed every other part of the ECPD program must depend upon the activities at local level of many members of the engineering profession in a concerted movement. Members of the local sections of all of the professional societies, and of local engineering councils, must be recruited for this work if it is to go forward. The ECPD itself has no such field organization, yet field organizations nevertheless must be established to operate under ECPD's leadership and guidance. It is this scheme of operations long since contemplated and thus far only imperfectly carried out.

OTHER SOCIETIES •

New ASRE Secretary. M. C. Turpin, acting secretary of the American Society of Refrigerating Engineers since June 1947, was elected secretary of the society at its 43d annual meeting in December. He

had been sales manager in the merchandising department of Westinghouse Electric Corporation, in its Washington office, for 15 years, although he was connected with the company since 1909. For many years he was engaged in the preparation of technical literature and articles for the trade press for Westinghouse, first editor of the company's house organ, president of Electric Institute of Washington, member of the Washington Board of Trade, and also charter member and chairman of the Baltimore–Washington section of the ASRE. Besides his activities as secretary of the society, he is also secretary of all ASRE technical and standards committees.

New VTA Officers. Frederick M. Damitz, president of the National Varnished Products Corporation, Woodbridge, N. J., has been elected president of the Varnished Tubing Association for a year's term. He long has been a prominent figure in the electrical insulation manufacturing field. John H. Finnegan of the Varflex Corporation, Rome, N. Y., has been elected vice-president of the association for a year's term. He is a leading figure in the field of electrical insulation manufacturing. Both men were elected at the trade group's 16th annual meeting at the Hotel Biltmore, New York, N. Y.

ACS News Editor Retires. James T. Grady, for 25 years publicist of the American chemical profession, retired December 31, 1947. During this period he served as managing editor of the American Chemical Society's news service. For 28 years Mr. Grady was director of the department of public information of Columbia University. While at Columbia he was public relations representative of many scientific, cultural, educational, and industrial organizations. The board of directors of the American Chemical Society has adopted a resolution in tribute to the "significant contribution he has made to the better public understanding of chemists and chemical engineers, and their contributions to public welfare." He will continue with the society in an advisory capacity.

Future Meetings of Other Societies

American Institute of Mining and Metallurgical Engineers. Annual meeting, February 15–19, 1948, New York, N. Y.

American Iron and Steel Institute. May 26–27, 1948, New York, N. Y.

American Society of Civil Engineers. Spring meeting, April 7–9, 1948, Pittsburgh, Pa.; summer convention, July 21–23, 1948, Seattle, Wash.

American Society for Engineering Education. June 14–18, 1948, Austin, Tex.

American Society of Heating and Ventilating Engineers. February 2–5, 1948, New York, N. Y.

American Society for Testing Materials. Spring meeting and committee week, March 1–5, 1948, Washington, D. C.; annual meeting, June 21–25, 1948, Detroit, Mich.

American Society of Tool Engineers. Sixth annual industrial exposition, March 15–19, 1948, Cleveland, Ohio.

Canadian Institute of Radio Engineers. Convention, April 30–May 1, 1948, Toronto, Ontario, Canada.

Chicago Technical Societies Council. Chicago Technical Conference and Chicago Production Show, March 22–24, 1948, Chicago, Ill.

CIGRE (International Conference on Large Electric High-Tension Systems). Biennial meeting, June 24–July 3, 1948, Paris, France.

Edison Electric Institute. Annual engineering meetings, May 3–5, 1948, Chicago, Ill.; annual convention, June 2–4, 1948, Atlantic City, N. J.

Electric League of Western Pennsylvania. Planned lighting exhibition and conferences, March 1–4, 1948, Pittsburgh, Pa.

Institute of Radio Engineers. Annual convention and radio engineering show, March 22–25, 1948, New York, N. Y.

Midwest Power Conference. Annual meeting sponsored by Illinois Institute of Technology, April 7–9, 1948, Chicago, Ill.

Minnesota Federation of Engineering Societies. 26th annual engineering convention and 3d annual engineering exposition, February 11–14, 1948, St. Paul, Minn.

National Academy of Sciences. April 26–28, 1948, Washington, D. C.

National Association of Broadcasters. 26th annual convention, week of May 17, 1948, Los Angeles, Calif.

National Association of Corrosion Engineers. Fourth annual conference and exhibition, April 5–8, 1948, St. Louis, Mo.

National District Heating Association. 39th annual meeting, May 18–21, 1948, St. Louis, Mo.

National Electrical Manufacturers Association. Winter convention, March 14–18, 1948, Chicago, Ill.

National Electrical Wholesalers Association. 39th annual convention, May 2–7, 1948, Buffalo, N. Y.

Southern Machinery and Metals Exposition. Third exposition, April 5–8, 1948, Atlanta, Ga.

HONORS • • • • •

Washington Award Goes to Vermont Senator

Titus G. LeClair (F '40) chairman of the Washington Award Commission, has announced the selection of Senator Ralph E. Flanders of Vermont as the recipient of this year's award (1948). The Washington Award is made annually to an outstanding engineer, a citizen or resident of the United States who has ably served human needs. It was established for the purpose of promoting a better appreciation by the public for able work accomplished by engineers for the public welfare and encouraging among engineers themselves a broader understanding of their opportunities for public usefulness.

The award is administered by a commission representing five engineering societies: the Western Society of Engineers, American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, American Institute of Electrical Engineers, and the American Society of Mechanical Engineers. Herbert Hoover received the first award in 1919 and his name heads an illustrious list including the names of Ambrose Swasey, Henry Ford, Arthur Compton, Vannevar Bush, C. F. Kettering, and others equally outstanding.

Senator Flanders, a past president of ASME, has been a leading mechanical engineer serving as president of the Jones and Lamson Machine Company and associating in engineering capacities with other machine tool manufacturers and designers. He has been interested in economic and social problems for a long time and has written many articles on these subjects. His activities as senator have evidenced his serious interest in the welfare and well-being of his fellow men.

IRE Announces Awards for 1948

The board of directors of the Institute of Radio Engineers has announced a number of awards for the year 1948.

The IRE Medal of Honor will be awarded to L. C. F. Horle (F '35) for "his contributions to the radio industry in standardization work, both in peace and war, particularly in the field of electron tubes, and for his guidance of a multiplicity of technical committees into effective action." L. C. F. Horle has been a practicing consultant, specializing in industrial standardization in the communications field since 1929. He is chief engineer of the Radio Manufacturers Association, in charge of the RMA data bureau. He was elected to fellow grade in IRE in 1925, and in 1940 he was president of the IRE. The medal is awarded in recognition of distinguished service rendered through substantial and important advancement in the science and art of radio communication. The recipient of this medal is named by the board of directors upon recommendation by the awards committee.

S. W. Seeley was named for the Morris Liebmann Memorial Prize for "his development of ingenious circuits related to frequency modulation." S. W. Seeley is director of the RCA industry service laboratories in New York City. He was elected to fellow grade in IRE in 1943. The Morris Liebmann Memorial Prize comprises the income from a donation by E. J. Simon, a fellow of IRE, to preserve the memory of Colonel Morris N. Liebmann, killed in action during World War I.

For the Browder J. Thompson Memorial Prize the directors named W. H. Huggins (A '43) for his paper on "Broadband Noncontacting Short Circuits for Coaxial Lines," which appears in three parts in the September, October, and November issues of the IRE *Proceedings* for 1947. W. H. Huggins is a radio engineer with the Army Air Forces at the Cambridge field station of Watson Laboratories. The Browder J. Thompson Memorial Prize comprises the income from a fund established by voluntary contributions to preserve the memory

of Browder J. Thompson, a director of IRE when he was killed in action during World War II while on a special mission for the Secretary of War.

These awards are to be conferred officially at the 1948 IRE national convention in New York on March 24, 1948.

A. R. Kemp Named One of Top Chemists

A. R. Kemp, rubber technologist and insulation engineer of Bell Telephone Laboratories, has been designated one of the country's ten ablest chemists in the field of rubber chemistry by his fellow experts in the American Chemical Society. He is a veteran of nearly 30 years' service with the Bell Telephone Laboratories, having joined them in 1918 after receiving his bachelor's and master's degrees from the California Institute of Technology. He also served for a year as a teaching fellow at that institution.

During nearly all of his time at the laboratories he has been concerned with organic research on rubber and other insulating materials. Among his many contributions was the development of paragutta, a special type of rubber insulation. He also has been active in the development of processes for the continuous vulcanization of wire and other rubber products. In recent years he has been especially active in the development of synthetic rubber compounds.

Mr. Kemp is a member of numerous scientific organizations and has published many papers in the fields of organic and analytic chemistry, rubber science and technology, and electrical insulating materials. More than 40 patents have been issued to him.

Honorary Memberships Conferred by ASCE

Honorary memberships were conferred upon four distinguished members of the American Society of Civil Engineers at the 95th annual meeting of the organization which was held in the Hotel Commodore, New York, January 21–24, 1948.

The men so honored are

John B. Challies, vice-president, Shawinigan Water and Power Company, Montreal, Canada, who has been a leader in conservation and use of Canadian water resources

Hardy Cross, professor of civil engineering and chairman of Yale University's civil engineering department, prominent in engineering education circles and best known for his method of determining stresses, which has been adopted widely in the teaching of engineering

William H. McAlpine, special assistant in the office of the chief of engineers, Washington, D. C., who has an outstanding record of achievement in the use and control of America's rivers

Karl Terzaghi, professor of the practice of civil engineering in the Harvard graduate school of engineering and an eminent soil mechanics authority

Comparatively few students study engineering because they want to teach. Most of those who become engineering teachers do so as a by-product of their graduate training in engineering. They accept assistantships or instructorships to continue eating while they study to become masters or doctors of engineering. Some discover that they like teaching well enough to take in their belts and forswear the attractions of technical employment. Others alternate between teaching and industrial employment. Any good young engineering teacher does not regard teaching as too much of a gamble because he feels that, whenever advisable, he can stop teaching and accept industrial employment.

Contrasted to this, the engineering graduate who embarks upon the career of teaching technical English, via graduate training in engineering communications, is apt to feel that he is "burning his bridges behind him" as far as industrial employment is concerned. Moreover, despite assurances of equal opportunity for advancement, he may be suspicious that the majority of composition classes will continue to be taught by instructors rather than by full professors. His arts brethren are not apt to grant him recognition for "scholarly achievements," and the engineering faculty may continue to regard him as a teacher of service courses. Altogether, it seems that recruiting engineers for "engineering communications" will require good salesmanship or a major depression. It is true that during the past war there was an excellent industrial market for technical writers but can this market be expected to remain active enough to induce graduates to specialize in "engineering communications?"

One criticism of English training which the authors seem to have overlooked is that it is poor timing to schedule "technical composition" in the freshman year. The students are conditioned against compositions on "A Beautiful Sunset" from grammar school days, and they do not become "technical" until their junior or senior year. Students need a rest from composition courses until they have written technical laboratory reports for a year and have had them criticized mercilessly for sloppy composition. They need to be convinced *by their engineering teachers* and through talks by *practicing engineers* at meetings of the student technical societies that facility in technical composition is a tremendous asset to all engineers.

With this background, most students can be brought to regard "technical composition" as the *important* course which it is, and teachers trained both in engineering and in English then might avoid disillusioning the students. The job of selling technical English cannot be unloaded entirely on any English teacher, regardless of how he is trained. The students all know that every teacher's own course is the most important one in the curriculum. But when engineering teachers admit that an English course is important—that makes an impression!

S. G. LUTZ (A '38)

(Chairman, electrical engineering department, New York University, Bronx, N. Y.)

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

English Teachers

To the Editor:

Since reading "Training English Teachers for Engineers" with much interest and sympathy, I feel impelled to commend the article. I also wish to add two general suggestions.

In the first place, having acquired one of the "English Instructors with the New Look," I would require that a portion of his or her time be devoted to educational or other engineering activity leading to extensive engineering writing. This should continue as long as the teaching position lasted.

In the second place, I would require all engineering faculty members to take refresher courses (so-called) from these same special English teachers. Such courses should be repeated at intervals by all engineering faculty members.

I have attended or have been a faculty member in two technical high schools and seven college or university grade engineering schools. I still remember the Baltimore Poly mechanics teacher of many years ago who told my class about the graduate who failed to get a position because of his use of "pore" English.

GORDON D. ROBINSON (A '17)

(1526 Washington Street, Evanston, Ill.)

To the Editor:

Professors Crouch and Zetler ("Training English Teachers for Engineers," *EE Dec '47 pp 1182–84*) have touched the heart of a difficult problem at all schools. There is no question but that engineers with graduate training in "engineering communications" would be more successful teachers of technical composition than the typical young liberal arts man. The chief difficulty would seem to lie in attracting engineering graduates to this profession rather than in organizing this curriculum.

Nucleus

To the Editor:

When I read on page 1174 of your December issue under "Glossary of Nuclear Terms," that the diameter of a nucleus is 10^{-2} centimeters, I could think only of the old nursery rhyme:

"What a large nucleus you have grandmother!"

There must be a slight error here somewhere!

R. B. SCHULTZ
(102 Metoxet Street, Ridgway, Pa.)

(*Editor's Note:* For grandmother's oversize nucleus, score another black mark against the compositor and the proofreader; factor of course should be 10^{-12} centimeters, as noted by student Schultz.)

December Cover

To the Editor:

Shame on *ELECTRICAL ENGINEERING* for calling Jones and Laughlin's Pittsburgh Works, Carnegie Steel's Edgar Thompson Works on your December 1947 cover.

Enclosed is a similar print from our files with correct title for this famous Pittsburgh night scene known to steel men the world over. "The Valley of Steel—extending for miles on both banks of the Monongahela River, the Pittsburgh Works of Jones and Laughlin Steel Corporation lights the night sky over the city."

R. D. MOSSMAN
(Manager of advertising, Jones and Laughlin Steel Corporation, Pittsburgh, Pa.)

To the Editor:

Several of us "ex-Pittsburghers" have been studying the front cover picture of this December's issue of *ELECTRICAL ENGINEERING*, and have noted the inside information that the picture is a night view of the Edgar Thompson works of the Carnegie Steel Company.

We feel convinced that this is the Oakland or "Soho" Pittsburgh view of the Jones and Laughlin Steel Corporation's mills: the auto road and street car underpass clearly shows, where it merges with Second Avenue, and above it is the railroad "Y" that comes from the railroad line that passes the United States Bureau of Standards "mine" and the Carnegie Museum power plant in Schenley Park; the Boulevard of the Allies' lights showing in the center background and rising to the right foreground, seems to agree with this location, and an old Cram's map of Pittsburgh seems to confirm this.

There is also another view farther up the Monongahela River, United States Steel near Rankin, that would give a very similar view, which would show both blast furnaces in the foreground, and open hearths across the river, but the track "Y", and the Boulevard of Allies' lights don't "check" with that scene. Also, at the Edgar Thompson works the 4-track Pennsylvania Railroad line exists, which does not appear in the picture. From what I can remember, the power lines for each respective steel mill group run along the river in a like manner.

But how about it, . . . from what location was this picture taken?

L. GRAHAM LEHMAN (A '41)
(Electrical Engineer, Navy Department, Washington 7, D. C.)

(*Editor's Note:* Credit to the keen eyesight of Naval researcher Lehman and Mr. Mossman; black mark to the editor; apologies to the steel mill involved.)

NEW BOOKS

"IES Lighting Handbook." Edited by R. W. McKinley. Illuminating Engineering Society, New York, N. Y., 1947, 856 pages, cloth-bound, 9 by 6 inches, $7.50. In simple terms and highly condensed style the book presents the accumulated knowledge of the past 41 years of lighting progress, evaluated and interpreted with respect to today's needs by a group of more than 100 contributing specialists—engineers, architects, physicists, decorators, artists, and opthalmologists. To aid in completing lighting installation plans, detailed data on many types of commercially available lighting equipment are included. In some instances it has been possible, for the first time, to simplify design techniques and other working tools so that they now may be used easily by everyone. Every precaution has been taken to secure broad coverage of all phases of lighting and a completely objective approach.

"The Science and Engineering of Nuclear Power." Edited by Clark Goodman. Addison Wesley Press Inc., Cambridge, Mass., 1947, approximately 500 pages, cloth-bound, $10\frac{1}{2}$ by $7\frac{3}{4}$ inches, $7.50 (paper-bound student's edition, $6). The book covers primarily the basic treatment of nuclear pile design and its practical application, in addition to background material necessary for their understanding. Allied subjects such as control, monitoring, chemistry of heavy elements, and fission products also are treated. Included is the Segré isotope chart which contains a fairly complete summary of some of the more important properties of nucleuses, both stable and radioactive.

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

ELECTRIC MACHINERY, Two Volumes. By M. Liwschitz-Garik, assisted by C. C. Whipple. D. Van Nostrand Company, New York, N. Y., 1946. Volume 1, 290 pages; volume 2, 576 pages, illustrations, diagrams, charts, tables, $9\frac{1}{4}$ by 6 inches, cloth, volume 1, $4; volume 2, $6.50. The author's principal aim is to provide the fundamental link between the basic laws of electrodynamics and the performance characteristics of electric machines. To this end common features are discussed in separate introductory chapters, such as: magnetic circuits of the main flux and of leakage fluxes, losses and cooling, windings and induced electromotive forces, and so forth. Although written primarily for students, special consideration is given to the demands encountered in practice. A separate index and a list of further references are included in each volume.

ENGINEERING, SCIENCE, AND MANAGEMENT WAR TRAINING; FINAL REPORT. By H. H. Armsby. Bulletin 1946, number 9. Federal Security Agency, United States Office of Education, 161 pages, diagrams, tables, 9 by 6 inches, paper, $0.35. A brief, factual outline is presented of the origin, development, principal operating characteristics, and general results of the college-level war training program conducted from 1940 to 1945. Part 1 is a narrative account of the basic principles, policies, and procedures, the contribution to the war effort, and the resulting permanent educational values. Part 2 sets forth in greater technical detail the authorizations, organizations, and methods of administration employed. There is a partial bibliography of articles from publications other than those of participating institutions.

TIME AND THERMODYNAMICS. By A. R. Ubbelohde. Oxford University Press, New York, N. Y., 1947. 110 pages, $7\frac{1}{2}$ by 5 inches, cloth, $2.25. This book deals with the significance of thermodynamics for certain problems of human observation and experience. So far as possible, nontechnical terms are used in describing the historical development of the concept of entropy for measuring the trend of events in time. Simple illustrations of important statistical equilibria also are given in order to reach a more fundamental understanding of the nature of time.

PAMPHLETS

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

Sound Information. Bulletin, 4 pp. Presents information widely used in the design of sound equipment in a brief form. The contents include a table showing impedance versus decibel loss, with values calculated for impedance mismatch, minimum "T" loss, and bridging-pad loss. Also included are data on mixer circuits showing circuit diagrams and applications. The Daven Company, 191 Central Avenue, N. J.

Performance Standards. This new publication seeks to establish a uniform basis for measuring the adequacy of building materials and home construction methods. The pamphlet proposes performance standards for structural elements of the house such as floors, walls, partitions, ceilings, and roofs, as well as data on insulation requirements. Available without charge from the Housing and Home Finance Agency, Washington 25, D. C.

Basic Radio Propagation Predictions for October 1947 three months in advance (NBS Publication CRPL-D35). Basic radio propagation predictions three months in advance with instructions for use. Superintendent of Documents, Government Printing Office, Washington 25, D. C., 15 cents.